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# TULANE STUDIES IN GEOLOGY AND PALEONTOLOGY

# TULANE STUDIES IN GEOLOGY AND PALEONTOLOGY

Volume 7

1969

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HUBERT C. SKINNER

*Editor*

TULANE UNIVERSITY OF LOUISIANA

New Orleans

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# THE ANADARID SUBGENUS *CALOOSARCA* IN THE WESTERN ATLANTIC REGION

HAROLD E. VOKES
*TULANE UNIVERSITY*

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## I. Abstract

Species referable to the anadarid subgenus *Caloosarca* Olsson, 1961, are distinguished by their broadly elongate valves with anteriorly located umbos and, especially in the younger stages of growth, a broadly emarginated posterior end that gives the valves an auriculate or winged outline. The ligament in the young and early mature stages is confined to the posterior portion of the cardinal area, extending anteriorly only to a point directly below the umbo, with the anterior portion of the area bare; in late mature and gerontic stages this an-

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terior portion may also be covered. The teeth on the hinge plate are in two series that meet immediately below a transverse groove on the cardinal plate which marks the anterior end of the normal ligamental structure.

Seven named species, differentiated primarily upon the number and nature of the radial ribs that ornament the valves, are recognized. A probable eighth species is represented by specimens dredged from upper Miocene deposits in the bed of the Caloosahatchee River, near Olga, Lee County, Florida, but present material is inadequate for description.

One species, *Anadara* (*Caloosarca*) *notabilis* (Röding), is living in relatively shallow waters from Florida to southern Brazil and has been reported from Pleistocene deposits from Cape Hatteras to Brazil. The other species are known only from the fossil record, with five of them being confined, so far as is presently known, to peninsular Florida. Two new species, *A.* (*C.*). *notoflorida* and *A.* (*C.*) *hoerleae,* are described from the upper Miocene, Pinecrest Formation; one species, *A.* (*C.*) *crassicosta* (Heilprin) occurs in the Pliocene, Caloosahatchee Formation; and two species, *A.* (*C.*) *aequalitas* (Tucker and Wilson) and *A.* (*C.*) *catasarca* (Dall), are confined to deposits referred to "Unit A" of Olsson and Petit, 1964, an as yet unnamed post-Caloosahatchee formation. The type of the subgenus, *A.* (*C.*) *rustica* (Tuomey and Holmes) is known only from the Pliocene, Waccamaw Formation of South Carolina and adjacent areas of southern North Carolina.

## II. Introduction

Among the more abundant elements in the fossil faunas collected from the Pliocene and early Pleistocene deposits of peninsular Florida are representatives of the anadarid subgenus *Caloosarca* Olsson, 1961. The Pliocene specimens, characterized by great divergence in the size of the ribs on the posterior portion of the median segment of the valves, have been almost universally identified in the literature as *Anadara rustica* (Tuomey and Holmes) following Dall's (1898, p. 653) error in placing *Anadara crassicosta* (Heilprin) in the synonymy of that Carolinian species (see Olsson and Petit, 1964, p. 527-528). The later Pliocene and early Pleistocene specimens with ribs on the median area of the valves of more equal strength have usually been referred to *Anadara aequalitas* (Tucker and Wilson).

During December, 1966, specimens of a relatively equi-ribbed species that clearly was different from *A. aequalitas,* were collected from spoil bank material of upper Miocene age that temporarily was available during the construction of the trans-Florida toll road, generally referred to as "Alligator Alley." Subsequently Mrs. R. E. Hoerle, of West Palm Beach, Florida, presented to Tulane University a collection of upper Miocene fossils that had been secured from material dredged from the Kissimmee River north of Lake Okeechobee. This collection included representatives of yet another undescribed species that showed characteristics more or less intermediate between the "Alligator Alley" species and the Pliocene *A. crassicosta.* As study of this material progressed it became evident that a careful review of the Tertiary and Recent species in the western Atlantic region was desirable and would prove a useful tool to students of these faunas.

In the present study the writer recognizes seven named species as being referable to the subgenus *Caloosarca.* In addition, three specimens dredged from the bed of the Caloosahatchee River one mile below Olga appear to represent an eighth species, but the material is not adequate for description. The named species here referred to *Caloosarca* include:

*Anadara* (*Caloosarca*) *notabilis* (Röding)—Upper Pliocene or lower Pleistocene, Moín Formation, Costa Rica; Pleistocene, Cape Hatteras, North Carolina to Brazil; Recent, Florida to eastern Texas and southward to Ilha Grande, Rio de Janeiro, Brazil.

*Anadara* (*Caloosarca*) *catasarca* (Dall)—"Unit A" (unnamed post-Caloosahatchee formation), Upper Pliocene or lower Pleistocene, southern Florida.

*Anadara* (*Caloosarca*) *aequalitas* (Tucker and Wilson)—"Unit A" (unnamed post-Caloosahatchee formation), Upper Pliocene or lower Pleistocene, southern Florida.

*Anadara* (*Caloosarca*) *crassicosta* (Heilprin)—Pliocene, Caloosahatchee Formation, southern Florida.

*Anadara* (*Caloosarca*) *rustica* (Tuomey and Holmes)—Pliocene, Waccamaw Formation, North and South Carolina.

*Anadara* (*Caloosarca*) *notoflorida* H. E. Vokes, new species—Upper Miocene, Pinecrest Formation, Collier, Lee and Charlotte counties, southern Florida.

*Anadara* (*Caloosarca*) *hoerleae* H. E. Vokes, new species—Upper Miocene, Pinecrest Formation, Kissimmee River, Highlands County, Florida.

## III. Acknowledgments

The present report is one of a series of generic studies of Tertiary and Recent Mollusca being supported by National Science Foundation grant GB-6048. The financial assistance and encouragement thus afforded is most gratefully acknowledged. The writer is also indebted to the authorities of the United States National Museum for the loan of numerous specimens, including the holotypes of *Anadara catasarca* (Dall) and *A. prephina* (Woodring). Mr. Druid Wilson of the United States Geological Survey has permitted the writer to draw on his extensive knowledge of the Florida Tertiary deposits and their faunas; Mr. Richard E. Petit of Ocean Drive Beach, South Carolina, made available the many specimens of *Anadara* (*Caloosarca*) *rustica* (Tuomey and Holmes) that he had collected during the construction of the airport facilities at Crescent Beach, South Carolina; Mrs. Robert C. Hoerle of West Palm Beach, Florida, presented to Tulane University extensive collections from southern Florida that included representatives of all of the species of *Caloosarca* here recognized from that area. Their generosity has been of much assistance during the preparation of this report.

## IV. Genus *ANADARA* Gray, 1847

Plate 1, figures 1-7

Type species, by original designation: *Arca antiquata* Linnaeus

The genus *Anadara* was established by Gray (1847, p. 198) in the following terms:

> "707. Anadara. Arca sp. *Linn., Lamk., Swains.* Pectunculus Anadara, *Adans.* 1757. Arca rhomboides, *Blainv.* Arca antiquata."

The *Arca antiquata* selected as the type is the species so named by Linnaeus (1758, p. 694) with references to illustrations by Buonanni, Rumphius, Sloane, and Gualtieri, and the habitat given as "O. Americano." There has long been uncertainty as to just what species should bear the Linnaean name. As noted by Dodge (1952, p. 149) the original description is "somewhat vague" and "the references, with the possible exception of the figure from Gualtieri, are valueless." Fortunately, however, there is a small, somewhat worn left valve in the original Linnaean collection that bears the specimen number "144" in Linnaeus' handwriting. This is the number assigned the species in the Tenth Edition of the Systema Naturae and the specimen "agrees in all respects with those few characters in the original description that are not too generalized" (Dodge, 1952).

The problem as to the exact identity of the species has stemmed largely from the Linnaeus citation of his form as from the "O. Americano." While there are superficially similar forms in that region, none agrees very closely with the admittedly poor original figures cited, nor with the specimen in the Linnaean collection. Species of *Anadara, sensu lato,* occur in the warmer waters of all parts of the world. Poli (1795, vol. 2, pl. 25, figs. 14, 15), and following him, Lamarck (1819, p. 42) identified as *Arca antiquata* a Mediterranean form now generally referred to *Anadara* (*Diluvarca*) *diluvii* (Lamarck), a species based upon a fossil shell from the same general region. It is to be noted, however, that Lamarck cited for his *Arca antiquata* "Habite l'Océan indien, les côtes d'Afrique, la Mediterranée." Bruguière (1789, p. 103-4) after citing the records of Rumphius ("l'île de Malacca"), Sloane ("Jamaique"), and Adanson ("Sénégal"), adds "je l'ai trouvée abondamment aux îles de France, de Bourbon & de Madagascar; & Forskhaels dans la mer Rouge." Thus even at this comparatively early date the assignment of the species as a member of the fauna of the "O. Americano" was in question.

Hanley (1855, p. 95) and after him, Dodge (1952, p. 150) suggested that Linnaeus was led into error regarding the locality from which his specimen came by "the erroneous figures he cited from Lister and Adanson . . . " (Dodge). Unfortunately Linnaeus did not cite either of these two authors in the original description of the Tenth Edition, adding them only in the Twelfth Edition where, however, he gives the locality as "Habitat in O. Americano, Africano." It seems more probable that the

assignment to the fauna of the "O. Americano" was based upon the citation to Sloane's "Natural History of Jamaica" in which that author states in the description of his *Pectunculus major polyginglymus hirsutus* (vol. 2, p. 257), "I found it in the Sea adjoining to Jamaica." Why that locality was given preference over that of Rumphius —"Amboina"—is of course not now known.

According to Hanley (1855, p. 94) "The original example, being much worn, was accompanied in the cabinet [of the Linnaean Society] by a perfectly fresh-looking specimen that had possibly been introduced by Sir J. Smith, to further illustrate the species." This latter specimen was figured by Hanley (1855, pl. 1, fig. 4) as *Arca scapha* Meuschen, 1781, with which species Hanley clearly initially identified the Linnaean specimen. "The type, however, having been subsequently pronounced by that eminent naturalist Mr. Cuming to be the *maculosa* of Reeve [1844, Conch. Icon., pl. 4, sp. 24] it has been thought desirable to give an engraving of it likewise (pl. 4, fig. 3)." A comparison of these figures with due allowance being made for the worn condition of the original Linnaean specimen, reveals the very close relationship of the two forms. Dodge (1952, p. 149-150) appears to believe that they are but varietally different, while Olsson (1961, p. 85) after a comparison of the specimens in question "supplemented by a few other shells at the British Museum (Nat. Hist.) believed to represent the same species" concluded that *A. scapha* and *A. maculosa* are synonyms, both of each other and of *A. antiquata* Linnaeus.

The Hanley figure of the Linnaean specimen represents an external view. Woodring (1925, pl. 4, figs. 1, 2) has given figures of its interior and dorsal aspects.

It is of interest to note that Chemnitz (1783, vol. 7, p. 201-205) included: "LINNAEI Syst. Nat. Edit. 10. no. 144. pag. 694." as one of the references to his discussion of his illustration, pl. 55, fig. 548. "Das Paquetboot. Arca Scapha . . . " His other citations include all of the references given by Linnaeus for his *Arca antiquata* in both the 10th and 12th editions of the Systema. Chemnitz cites the locality references of many of the authors listed, but states that the original of his figure came from the Red Sea.

Collections made during the ninth cruise of the RV *Anton Bruun* in the western

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PLATE 1

Figures Page

*Anadara* (*Anadara*) *antiquata* (Linnaeus) ..... 3

1, 2, 3, 5, 7. USNM 694045, paired valves, length 49.8 mm, height 38.7 mm, diameter 30 mm. Locality, Pamanzi Island, near Mayotta, Comorro Group, Indian Ocean. 1. Exterior of right valve; 2. Oblique view of anterior end, right valve; note median grooves on ribs. 3. Exterior, left valve; 5. Hinge and interior of right valve; note weakening of marginal denticulations toward anterior end of ventral margin. 7. Dorsal view of conjoined valves.

4, 6. USNM 694046, paired valves, length 77.6 mm, height 60 mm, diameter 58 mm. Locality, between West and Polymnie Islands, Aldabra Group, Indian Ocean. 4. Dorsal view of gerontic specimen; note irregular ligament grooves. 6. hinge view.

*Anadara* (*Caloosarca*) *notabilis* (Röding) ..... 30

8. USNM 694047, left valve, length 52.5 mm, height 39 mm. Locality TU R-109.

9, 10. USNM 694049, paired valves, length 33 mm, height 26.1 mm, diameter 21.5 mm. Locality TU R-109. 9. Exterior of right valve with preserved remnants of periostracum; 10. Dorsal view of conjoined valves; note smooth anterior end of cardinal margin.

11, 12. USNM 694048, right valve, length 47.8 mm, height 35.8 mm. Locality TU R-109. 11. Hinge and interior of valve; 12. Exterior of right valve; note grooved anterior ribs.

Figure 2 slightly enlarged, all others approximately natural size.

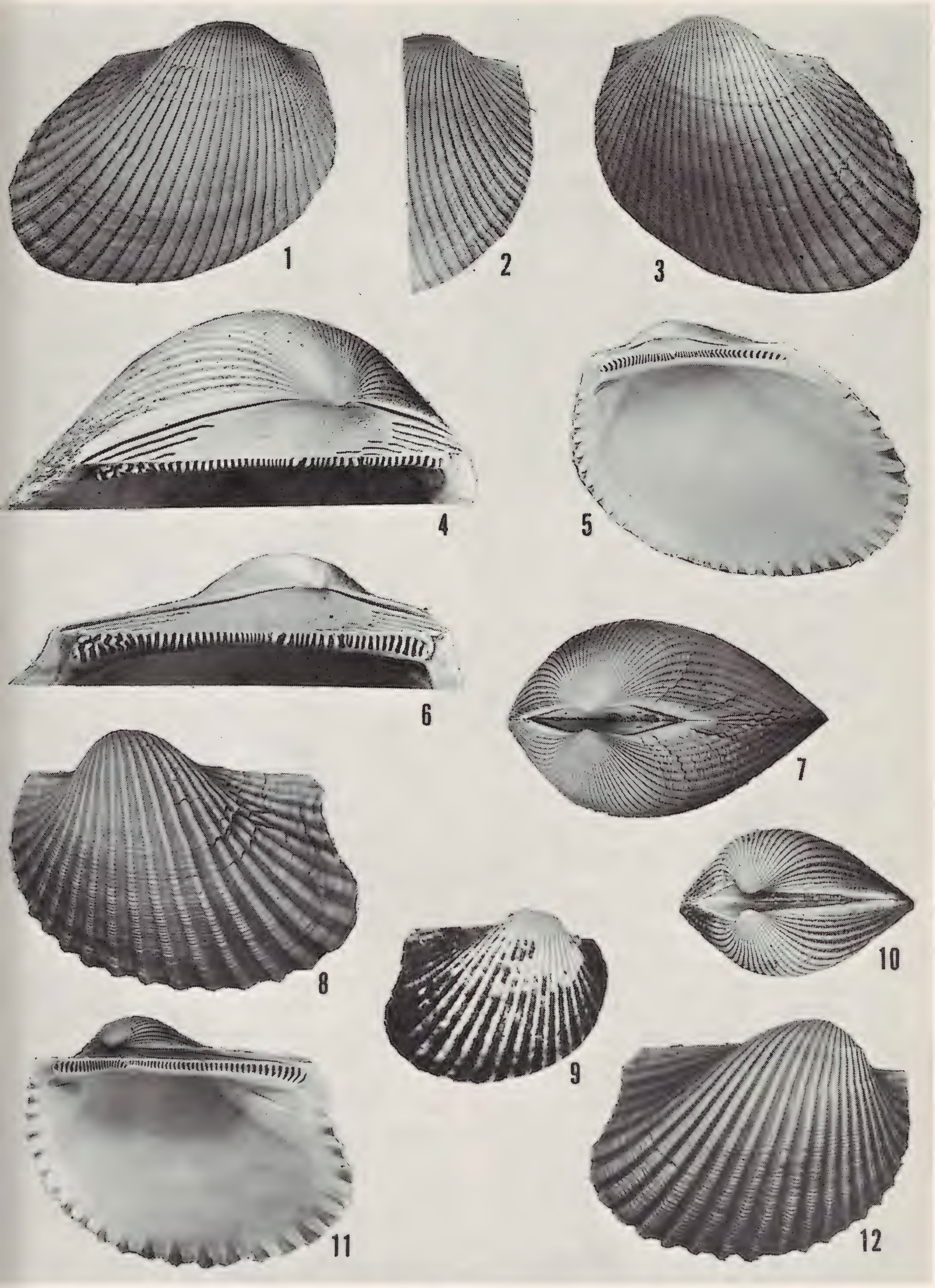



PLATE 1

part of the Indian Ocean contain numerous specimens from the coast of Kenya and Tanzania, as well as from the islands of the Seychelles and Comorro Groups. It is also common in collections that I made in 1952-53 in the Philippines, and is listed by Smith *in* Gardiner (1906, p. 597) from the Maldive and Laccadive Archipelagos. Reeve's type of his *Arca maculosa* was cited as from "North coast of New Holland" while Rippingale and McMichael (1961, p. 167) cite "*Anadara maculosa* Reeve (= *antiquata* olim)" as ranging from "Melanesia and Queensland to the Northern Territory" [of Australia]. Kira (1962, p. 124, pl. 44, fig. 12) indicates the range as "south of Amami Islands to the Philippines, in shallow waters." The species thus seems to range throughout the warmer waters of the western Pacific Ocean and the Indian Ocean to the Red Sea.

The recognition of the fact that the name *Arca antiquata* Linnaeus, 1758, is to be applied to the species that has generally been denominated *Arca scapha* Meuschen, 1781 (an invalid name having been published in a non-binomial work, see Opinion 261, Int. Comm. on Zool. Nomenclature) or *Arca maculosa* Reeve, 1844, permits a more precise definition of the genus *Anadara, sensu stricto*. The shell is of medium to relatively large size, equivalved, inequilateral, and rather strongly inflated. The largest specimen in the Indian Ocean collections, a somewhat worn pair of valves from the lagoon at Aldabra atoll in the western Indian Ocean, has the following dimensions: length, 77.6 mm, height, 60 mm, diameter (paired valves), 58 mm. Measurements of a number of adult specimens show a height : length ratio varying between 1:1.23-1.29, and a height : diameter (paired valves) ratio between 1:.72 (in younger individuals)-.96 (in larger, more or less gerontic specimens). The small, prosogyrate umbones are situated just slightly behind the anterior fourth of the total length of the valve, but are slightly posterior to the anterior third of the length of the cardinal area. The length of this structure varies from slightly more than one-half the total length of the valve in relatively oblique specimens, being .57 of the length in the specimen illustrated (Plate 1, fig. 5) to three-fourths of the total length in the larger, more gerontic forms. The ratio of total length to the length of the cardinal area in the large specimen from Aldabra, mentioned above, is 1:.756 (Plate 1, fig. 6).

The cardinal area in living specimens is always completely covered by a thick, dark brown to black ligament which tends to exhibit transverse striations. It is set into deep grooves that are located at the outer margins of the area. In specimens of average size these marginal grooves are the only insertion structures on the area, which is smooth except for faint striations that appear to represent remnant patterns induced by the growth of the hinge teeth. Older specimens occasionally develop ligament insertion grooves that may be parallel to the outer margins of the area as incomplete chevrons, or, more commonly, are parallel to the hinge plate as short, disjunct lines (Plate 1, fig. 4).

The sculpture is essentially similar in both valves and consists of numerous, closeset ribs. A count of 50 valves in the collections from the Indian Ocean area gives the following result:

| No. of ribs: | 33 | 34 | 35 | 36 | 37 | 38 | 39 |
|---|---|---|---|---|---|---|---|
| No. of specimens: | | | | | | | |
| Right valves | 1 | 2 | 5 | 7 | 5 | 4 | 1 = 25 |
| Left valves | 0 | 4 | 5 | 6 | 5 | 4 | 1 = 25 |
| Total | 1 | 6 | 10 | 13 | 10 | 8 | 2 = 50 |

Initially the ribs are simple, separated by interspaces that are about one-half the width of the adjacent rib, relatively flat-bottomed, but ornamented by raised threads that under the microscope appear as the projecting portions of shingled growth increments. These same lirations also cross the radial ribs but are much subdued and inconspicuous except on the anterior end of the shell where they may, on well-preserved specimens, appear as narrow transverse beading. Early in the development of the valve a median groove develops on the tops of the ribs. This first appears on the anterior portion of the valve (Plate 1, fig. 2), then, usually, on the posterior portion, developing on the median surface of the shell only in relatively late adult stages. Subsequent to the development of the median grooves secondary grooves may appear on each side of them giving the ribs a quadripartite appearance. These first tend to develop on the ribs that mark the area of the margin between the posterior

and ventral surfaces of the shell and appear on the anterior ribs only late in development. The time of appearance of the median grooving is variable. Thus one specimen from near Mayotta in the Comorro Island group that is but 7.7 mm long has such grooves on two millimeters of the length of the anterior ribs; while another from the same locality with a length of 20.4 mm shows no trace of such grooving. The median grooves show quite well on the figure of the Linnaean type specimen given by Hanley (1855, pl. 4, fig. 3).

The hinge line is straight; the teeth arranged in a series that may or may not be interrupted near the middle of the hinge-length posterior to the umbones. Immature specimens show a slight arching of the toothrow, with the posterior series tending to override the anterior one. In these forms the teeth in the middle portion of the valve are transverse to the hinge plate, with the lateral teeth being divergent. Very small specimens, up to about 5 mm in length, show a small notch in the ventral side of the hinge plate immediately below the median interruption of the two series. In the right valve figured (pl. 1, fig. 5) the anterior series has 20 teeth, the posterior 38. The median nine or ten teeth in each series are relatively thin and transverse in position, but the lateral teeth become more chevron-shaped with the apex of the chevron pointing toward the median tooth elements. This chevron structure is first achieved by a lateral bending of the dorsal portion of the tooth elements such that in those teeth adjacent to the central part of the hinge plate only about the upper fourth of the tooth length is at an angle. The point of angulation tends progressively to become more ventral in location and the most distal elements on either end of the toothrow have the chevron angulation at approximately the middle of the tooth height. Tooth number is moderately constant, but shape is very plastic and variable. Thus, though almost all adult specimens of average size show 19 to 21 teeth in the anterior series and 26 to 29 in the posterior one, approximately one-half of the same specimens will lose the chevron fold in the outer six to eight teeth of the posterior series. In the majority of specimens these tend to be essentially transverse, although with a slight slope such that the dorsal end of a given tooth is somewhat more lateral in position than is the ventral end. Most gerontic specimens have the majority of the teeth directly transverse in position, with only those teeth at the anterior and posterior ends of the hinge plate modified, usually to a chevron-shape. In the largest specimen, mentioned above, the anteriormost teeth are not greatly altered, but the posterior lateral teeth are exceedingly irregular in shape (Pl. 1, fig. 6).

The anterior and posterior adductor scars are of moderate size and not strongly delimited in specimens of average size. Older individuals, however, show a strong tendency towards a thickening of the shell in the region of the anterior adductor until, in truly gerontic individuals there is a definite platform upon which this adductor is attached. The pallial line is entire and not strongly marked except for the fact that there is, near the postero-ventral end, a series of irregular raised ridges separated by rounded grooves that trend normal to the pallial line and extend inward from that structure toward the median portion of the valve.

The ventral margin of the shell is crenulated on its inner side. These crenulations are most strongly developed along the postero-ventral margin but are also well represented on the anterior and posterior ends of the valve. They become weak and relatively inconspicuous toward the anterior end of the ventral margin. This is well shown on the illustration of the Linnaean type given by Woodring (1925, pl. 4, fig. 1) who interpreted it as indicating that the species represented must have had a byssal gape (1925, p. 41); Dodge (1952, p. 149) appears to have interpreted it as a feature resultant from excessive wear in the specimen concerned. It is, however, to be observed in all specimens examined in the present study, including those that were taken alive with full, unworn periostracum. None of these same specimens show more than an exceedingly narrow linear gape in this area (0.3 mm wide in the smaller specimen figured) and none of the preserved animals in the collections reveal any byssal development. It is of interest to note that the weakening of the crenulations in the antero-ventral position is less pronounced on the specimens in the collections

from the Philippine Islands than it is in those from the western part of the Indian Ocean. Indeed this seems to be the one relatively constant character upon which the specimens from the two areas could be distinguished. It suggests that the original Linnaean type must have been from an Indian Ocean or Red Sea locality.

The reason for this weakening of the crenulations in the area in which a byssal gape would occur if present may possibly be taken as suggesting that the modern *Anadara antiquata* was evolved from a byssiferous ancestral species. This suggestion receives some added support in the fact that the umbones of many specimens reveal weak fold-depressions similar to those found in byssiferous species. These are often quite pronounced in shells of 5 to 10 mm total length, but even here, no trace of a true byssal gape can be detected.

Rumphius (1711) states that the species indicated in his pl. 44, fig. 1, which he denominated as *Pecten virgineus* was known among the Malaccans as "*Bia Anadara.*" This statement was noted by Chemnitz (1783, p. 202) ". . . a Maleicensibus Bia Anadara vocatur." In the meantime Adanson (1757, 248, pl. 18, fig. 7) used the vernacular "Anadara" for a similar species that was cited by Linnaeus in his synonymy of *Arca antiquata* in the 12th edition of the Systema Naturae and the term appears to have achieved rather wide acceptance as a vernacular name for species of this general form, particularly among the French conchologists. Thus Bruguière (1789, p. 103) uses the heading:

"12. ARCHE anadara.
Arca antiquata; LINN."

while also stating (p. 104) that the species is known as "Anadara, *coeur en arche de Noé*; par les Francois." Lamarck (1819, p. 42) used "26. Arche anadara. *Arca antiquata.*" It remained for Gray (1847, p. 198) to use the name in a formal scientific sense.

*Dimensions*:

Figured Specimen, USNM 694045: length 49.8 mm; height 38.7 mm; diameter (paired valves) 30 mm. Locality: Reef flat southwest of Pamanzi Island, near Mayotta, Comorro Group, Indian Ocean.

Figured Specimen, USNM 694046: length 77.6 mm; height 60 mm; diameter (paired valves) 58 mm. Locality: Reef flat at main channel between West and Polymnie Islands, Aldabra Group, Indian Ocean.

## V. Subgenus *CALOOSARCA* Olsson, 1961

Type species, by original designation: *Anadara rustica* (Tuomey and Holmes). Pliocene, North and South Carolina.

Olsson's (1961, p. 98) original description of this subgenus was as follows:

"Shell broadly elongate, moderately heavy, equivalve, convex. Cardinal area elongate, rather low or narrow, not covered fully by the ligament, the small portion anterior to the beaks usually bare. Posterior side deeply impressed, often winged or emarginated. Ribs simple, plain or heavily noded and often differing considerably in size, the anterior set sometimes mesially grooved. Hinge teeth small, numerous and in a continuous series.

"In the average specimen of *A. rustica,* the cardinal area in front of the beak is bare, but in gerontic specimens the anterior area may be partly covered or furrowed with ligamental grooves. In *A. notabilis* of the Caribbean, the cardinal area has essentially the same characters as in *A. rustica.*"

There has existed in the literature a considerable degree of misunderstanding as to the distribution of the species selected by Olsson to typify his subgenus. This stems from the work of Dall (1898, p. 653) who synonymized the Florida Caloosahatchee species, *Arca crassicosta* Heilprin, with the Carolinian Waccamaw form, *Arca rustica* Tuomey and Holmes, stating (p. 654): "The collection of more material since Professor Heilprin's publication leaves no doubt whatever as to the identity of this splendid species with that of Tuomey and Holmes." The original Tuomey and Holmes description was based upon very inadequate material, and the species is generally rare, becoming well known only after a considerable number of specimens became available through dredging for fill at the airport at Crescent Beach, South Carolina. Study of this material re-establishes the identity of *A. crassicosta* as a species distinct from the Waccamaw form (Olsson & Petit, 1964, p. 527-8).

At the time of the original publication

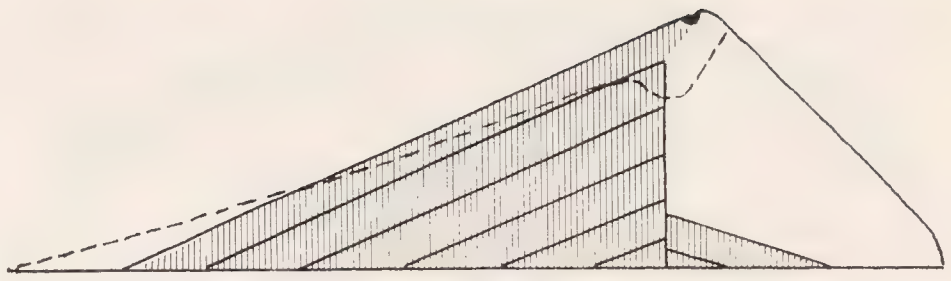
of the name *Caloosarca* Olsson clearly accepted Dall's conclusions as stated above, and gave the range of his *Anadara rustica* as "Pliocene of South Carolina and Florida." This fact, together with the selection of the subgeneric name *Caloosarca,* obviously based upon the name of the Florida, Pliocene, Caloosahatchee Formation, has raised some question as to whether or not this might be considered as a genus based upon a misidentified type species with consequent referral to the International Commission on Zoological Nomenclature (see International Code of Zoological Nomenclature articles 65 (b) and 70 (a)). This seems an unnecessary complication in the present case since there can be no doubt whatsoever but that the two species concerned are congeneric. However, Olsson's reference to the occurrence of the type species in the Pliocene of Florida should be deleted.

The subgenus first occurs in the western Atlantic faunas in the Upper Miocene of Florida and is represented in the Pliocene of North and South Carolina and Florida, the Pleistocene of North Carolina to Brazil, and in the Recent faunas from Florida to southern Brazil. Olsson also refers to this subgenus the Recent Panamic species *Arca biangulata* Sowerby (1833, p. 21), with which is synonymized *Arca gordita* Lowe (1935, p. 16, pl. 1, fig. 1).

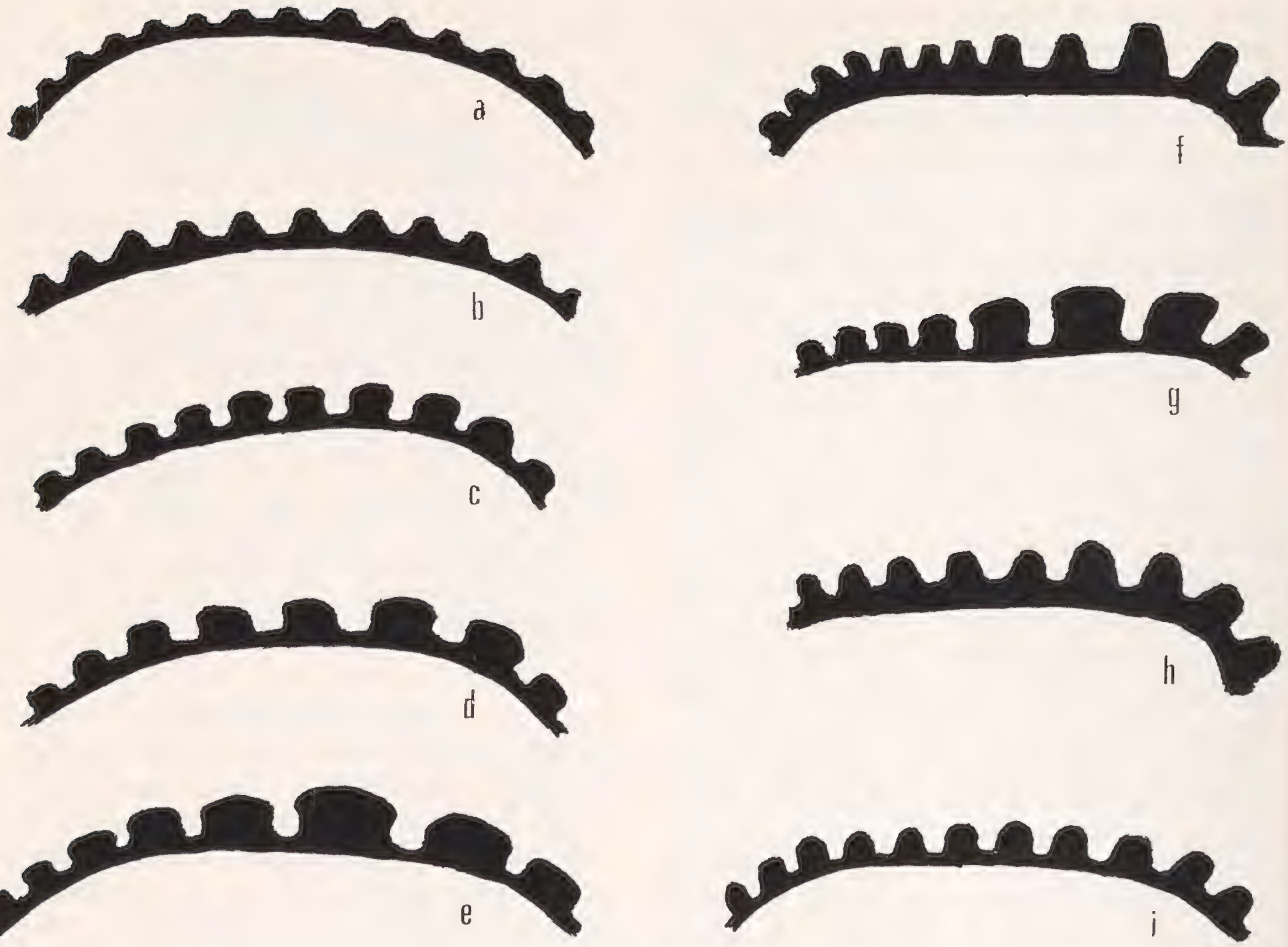
On the basis of the present study of the type and other species here referred to the subgenus *Caloosarca* the following revised description may be given for the subgenus:

Shell broadly elongate, moderately heavy, equivalve, strongly inequilateral with the relatively high, usually inflated umbos situated at, or in front of, the anterior fourth of the total length. Posterior side deeply impressed, winged or emarginate, especially in the earlier stages of growth. Ribs alternate in position on the two valves, simple, usually high, in some species differing considerably in size, especially near the posterior end of the median portion of the valve. Anterior ribs sometimes mesially grooved. All ribs more or less noded by raised growth increments which occur at regular intervals and are present on both ribs and interspaces.

Cardinal area elongate, moderately narrow, widest immediately in front of the umbones and sharply delimited posterior to them by a strong ridge formed by the dorsal margin of the main portion of the valve. Ligament in adolescent and early mature stages confined to the area posterior to the umbo, its anterior end marked by a groove extending transversely across the cardinal area from a position immediately below the umbo to a point immediately above the junction of the anterior and posterior tooth series on the hinge plate (see text fig. 1). Ligament apparently present over the entire posterior area at all stages of development, inserted in a groove immediately below the posterior dorsal ridge and with secondary grooves more or less irregularly parallel with the margin of the area. In late adult and gerontic stages the ligament tends also to occupy the anterior portion of the area, inserted into grooves that make essentially the same relative angle with the hinge line as do those of the posterior series and are never subparallel with the outer margin of the cardinal area as are those of the posterior series. On some specimens the anterior grooves are confluent posteriorly with the anterior end of the posterior grooves to form chevron-shaped structures, in others the anterior ones may terminate posteriorly at a position intermediate between the anterior ends of adjacent posterior grooves. While the time of development of the anterior segment of the ligament varies, in most species there are three to five posterior grooves prior to the first of the anterior ones.



Text figure 1. Diagram of cardinal area in *Caloosarca* showing portion covered by fibrous ligament (shaded). The small black area at the apex marks the initial position of the protoconch, the dashed line outlines the portion covered by the overhang of the umbo and posterior dorsal margin of the adult valve. Note that the anterior end of the ligament moves to a slightly more posterior position between the marginal insertion groove and the first subsequent ligamental groove and is then bounded anteriorly by a shallow groove that crosses the area transversely. The discontinuity between the anterior and posterior series of hinge teeth occurs immediately below this transverse groove.




Text figure 2. Profiles of the ribs on the median area of left valves of species referred to *Anadara* (*Caloosarca*).

a. *A.* (*C.*) *notabilis* (Röding).
b. *A.* (*C.*) *catasarca* (Dall).
c. *A.* (*C.*) *aequalitas* (Tucker and Wilson), typical form.
d. *A.* (*C.*) *aequalitas* (Tucker and Wilson), specimen transitional to *A.* (*C.*) *crassicosta* (Heilprin).
e. *A.* (*C.*) *crassicosta* (Heilprin).
f. *A.* (*C.*) *rustica* (Tuomey and Holmes), typical form.
g. *A.* (*C.*) *rustica* (Tuomey and Holmes), specimen with broad posterior ribs similar to those on *A.* (*C.*) *crassicosta* (Heilprin).
h. *A.* (*C.*) *hoerleae* H. E. Vokes, new species.
i. *A.* (*C.*) *notoflorida* H. E. Vokes, new species.

Hinge line straight, the teeth in two series with the anterior end of the posterior series dorsal to the termination of the anterior one and immediately below the position of the transverse groove of the cardinal plate. The longer posterior series with two and one-half to three times as many teeth as the shorter anterior series. Teeth generally transverse to the hinge plate, narrow, with their sides irregularly grooved. The distal teeth in the posterior series often show a tendency to develop a weak chevron-shape, usually with the apex of the chevron pointing anteriorly, but modification of individual teeth, including partial abortion may occur at any position in either series.

Inner margins of the valves strongly crenulated by the external radial ornamentation, the crenulations usually terminating near the well-marked, entire, pallial line. Interior of the valve pectinated by regularly spaced grooves that are most strongly developed just above the pallial line and immediately anterior to the posterior adductor scar. Adductor scars large, well marked, the anterior subtriangular in shape, the posterior more elongate, situated on a thickened smooth "plate" which is separated from the ventral side of the hinge plate by a distinct anal groove. Pedal retractor and/or diductor scars localized on the ventral side of the hinge plate, well marked.

On the basis of this redefinition of the subgenus, seven (possibly eight) species

present in the upper Miocene to Recent faunas of the western Atlantic area are here referred to *Caloosarca.* Two of these, *Anadara* (*Caloosarca*) *hoerleae,* n. sp., and *A.* (*C.*) *notoflorida,* n. sp., are from the upper part of the Pinecrest Formation, upper Miocene, of peninsular Florida. *A. hoerleae* occurs in deposits that Olsson (*in* Olsson and Petit, 1964, p. 517) has termed "The Brighton Facies" north of Lake Okeechobee, while *A. notoflorida* has been collected only from beds at Acline, Charlotte County, and from spoil bank material temporarily available during the construction of the new trans-Florida toll road that has been termed "Alligator Alley." In both areas the species is associated with *Vasum* (*Hystrivasum*) *locklini* Olsson and Harbison, suggesting that *A.* (*C.*) *hoerleae* and *A.* (*C.*) *notoflorida* are approximately of contemporaneous occurrence. The possible eighth species, in this report designated as "*Anadara* (*Caloosarca*), new species?," occurs in association with a specimen of *A.* (*C.*) *notoflorida* in a collection from material dredged from the bed of the Caloosahatchee River one mile below Olga, Lee County, Florida. It appears, in some characters, to be intermediate in position between the two described upper Miocene forms and *A.* (*C.*) *rustica* (Tuomey and Holmes), from the Waccamaw Formation, Pliocene, of South Carolina and adjacent areas of southern North Carolina, and *A.* (*C.*) *crassicosta* (Heilprin) from the essentially contemporaneous Caloosahatchee Formation of peninsular Florida.

*Anadara* (*Caloosarca*) *aequalitas* (Tucker and Wilson) is most abundant in collections made in the vicinity of the present Lake Okeechobee from strata that have been termed "Unit A" by Olsson and Petit (1964, p. 521) representing an as yet unnamed post-Caloosahatchee formation which is of uppermost Pliocene or early Pleistocene age. In its earliest occurrences it may be contemporary with *A.* (*C.*) *crassicosta* with which it occurs in collections from Tulane University localities 79 and 529. Unfortunately these are spoil bank collections that may represent more than one stratigraphic unit. The specimens in these two collections, however, are transitional between the two species and seem clearly to establish the evolution of *A.* (*C.*) *aequalitas* from *A.* (*C.*) *crassicosta.* Within the deposits as-

| *Anadara (Caloosarca)* | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | Number of Specimens Counted |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *notabilis* (Röding) | – | – | – | – | – | – | – | – | – | 7 | 42 | 82 | 41 | 25 | 3 | 200 |
| *catasarca* (Dall) | – | – | 2 | 14 | 37 | 45 | 38 | 38 | 20 | 3 | 3 | – | – | – | – | 200 |
| *aequalitas* (Tucker & Wilson) | 12 | 32 | 54 | 43 | 33 | 20 | 6 | – | – | – | – | – | – | – | – | 200 |
| *crassicosta* (Heilprin) | – | 1 | 22 | 80 | 72 | 21 | 3 | 1 | – | – | – | – | – | – | – | 200 |
| *rustica* (Tuomey & Holmes) | – | – | – | – | – | – | 4 | 6 | 16 | 14 | 4 | 1 | – | – | – | 45 |
| new species ? | – | – | – | – | 2 | – | – | – | 1 | – | – | – | – | – | – | 3 |
| *notoflorida* new species | – | – | – | – | – | 8 | 18 | 16 | 8 | – | – | – | – | – | – | 50 |
| *hoerleae* new species | – | – | – | – | – | 1 | – | 3 | – | – | – | – | – | – | – | 4 |
| | | | | | | | | | | | | | | | Total number of specimens counted: | 902 |

TABLE 1. Number of radial ribs on species of *Anadara* (*Caloosarca*) recognized in this report. All true ribs are counted, but the thickened anterior and posterior rim of the cardinal area is not included.

signed to "Unit A," *A. (C.) aequalitas* occurs most abundantly at localities where the matrix contains a fairly high lime mud content. At those localities where the lime mud element is reduced in amount and the matrix is generally a relatively fine-grained sand we find *Anadara (Caloosarca) catasarca* (Dall) to be the dominant species with *A. (C.) aequalitas* usually rare or absent.

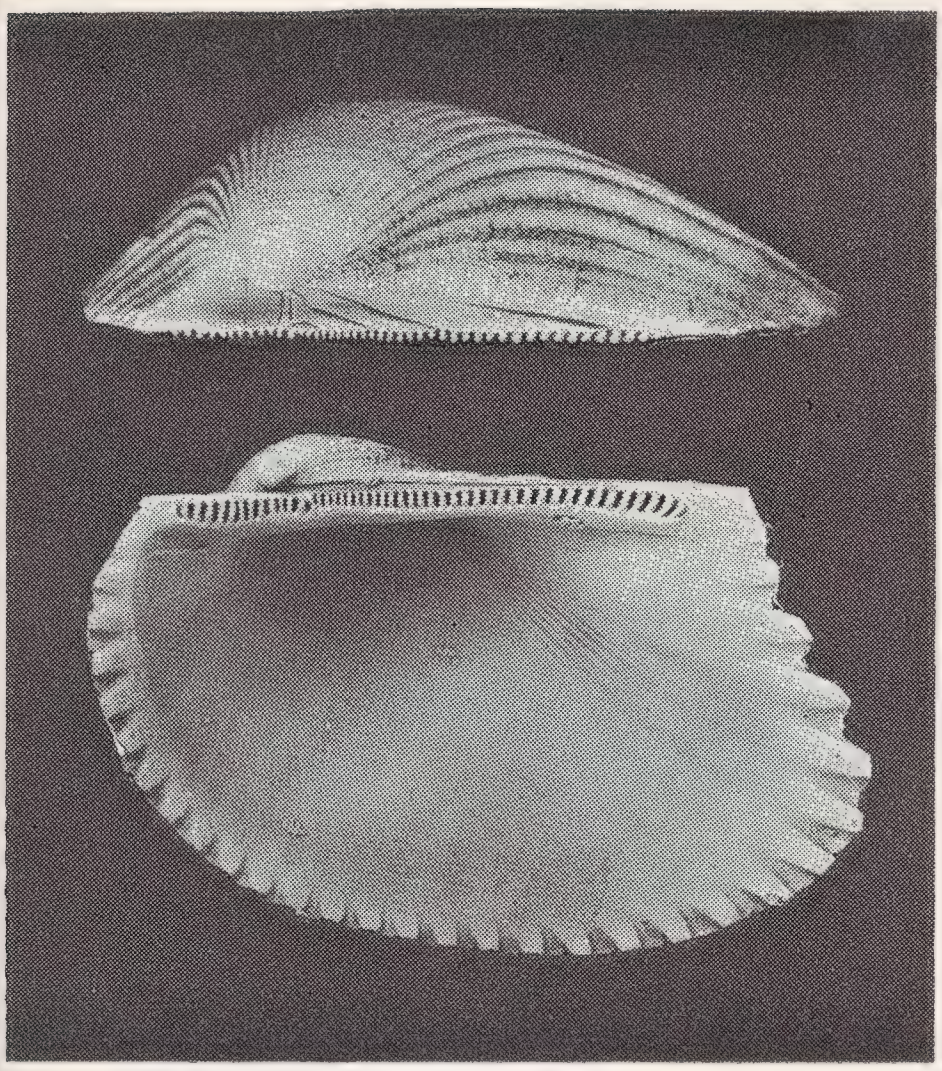
*Anadara (Caloosarca) notabilis* (Röding) is the only representative of the subgenus that is yet living in the waters of the western Atlantic area, ranging from Florida to southern Brazil. The oldest certain record of its occurrence seems to be from the Moín Formation of Costa Rica which appears to be contemporaneous with "Unit A" of the Florida section.

While there is some recognizable variation within these species in the expression of the characteristic hinge and cardinal area structures, as well as in the degree of inflation of the valves, the most useful characters for specific identification are to be found in the number of radial ribs (see Table 1) and in the variation in their size and shape on the median area of the valves, as well as in the size and shape of the interspaces that separate them (see Text fig. 2).

There are a number of superficially similar species, particularly in the middle and upper Miocene deposits of the western Atlantic region. These forms tend, like *Caloosarca,* to have the anterior end of the cardinal margin smooth in the younger stages of development, and the teeth in two series. But in all cases the anterior termination of the earlier, posterior portion of the ligament is situated well behind the umbos, usually only slightly in advance of the midlength of the area, and there is no transverse groove marking the anterior end of the early ligament growth. The two series of teeth, which overlap in a manner similar to that of the species of *Caloosarca,* meet below the anterior termination of the early posterior portion of the ligament and hence only slightly in advance of the midlength of the hinge plate. Furthermore, they are as a result more nearly equal in the number of teeth present in each series, the posterior usually having but one and one-quarter to one and one-half times as many teeth as the anterior. The outer, terminal teeth in the posterior series often tend to be somewhat inclined, rather than transverse in position as they are in *Caloosarca.* Exteriorly the shells are transversely elongate, ornamented by radial ribs that are never as high and strongly developed as in *Caloosarca;* the posterior end is not as deeply emarginate, the postero-ventral umbonal ridge never as strongly developed, and the shell is but slightly, if at all auriculate posteriorly. The ventral margin tends, in most of these species, to be broadly rounded, rather than relatively straight.

Included in this group of Miocene species are: *Anadara campsa* (Dall) (1898, p. 656, pl. 32, fig. 21) from the upper Miocene, Jackson Bluff Formation of northern Florida; *A. inaequilateralis* (Guppy) (1866, p. 293, pl. 18, fig. 2), *A. halidonata* (Dall) (1898, pl. 646, pl. 33, fig. 24), and (?) *A. dasia* (Woodring) (1925, p. 44, pl. 4, fig. 7) from the upper (?) Miocene, Bowden Formation of Jamaica; *A. istmica* Perrilliat Montoya (1960, p. 12, pl. 1, figs. 3-5) and *A. woodringi* Perrilliat Montoya (1960, p. 13, pl. 2, figs. 3-10) from the upper Miocene, Agueguexquite Formation of the Isthmus of Tehuantepec area of Mexico; *A. actinophora* (Dall) (1898, p. 185, pl. 33, fig. 26) and an apparently undescribed species in the Tulane University collections from the middle Miocene, Gatun Formation of Panama; and *A. guayubinica* (Maury) (1917, p. 170, pl. 28, fig. 4; pl. 29, fig. 1), and *A. riogurabonica* (Maury) (1917, p. 170, pl. 29, fig. 4) from the middle Miocene, Gurabo Formation of Santo Domingo. The Recent species, *A. hemidesmos* (Philippi) (1845, vol. 2, p. 31, *Arca,* pl. 2, fig. 5) from Cuba and Martinique (*fide* d'Orbigny, 1845, p. 345-6, as *hemidermos*), and *A. baughmani* Hertlein (1951, p. 487, pl. A, figs. 1-7) from 40 fathoms off the coast of Texas appear to be descendants of this Miocene group.

It seems most probable that the species referable to *Caloosarca* have been derived from among the Miocene species of this group. Structurally the Bowden species *Anadara prephina* (Woodring) (1925, p. 44, pl. 4, fig. 8) is almost intermediate in position, having the external shape with rounded ventral margin, weaker posterior umbonal ridge, and but slight posterior



Text figure 3. Dorsal and interior views of holotype right valve (USNM 352754) of *Anadara prephina* (Woodring). Note the *Caloosarca*-like nature of the hinge and cardinal area.

emargination, plus numerous, lower, radial ribs such as characterize the typical Miocene forms mentioned above. The hinge and ligamental areas are, however, very similar to those found in *Caloosarca.* The ligament, while confined to the region posterior to the umbos, extended anteriorly to a position almost directly beneath the beaks, with a well-developed transverse groove marking its anterior termination (text fig. 3). The junction between the anterior and posterior tooth series is similarly more anterior in position than is typical of the Miocene species cited above, and almost identical with the location found in *Caloosarca.* The anterior series, in the holotype specimen, has 14 teeth while the longer posterior series has 34 (text fig. 2), a 1:2.5 ratio that agrees more closely with that observed in typical species of *Caloosarca* than it does with the 1:1.25 to 1:1.5 ratio noted in the Miocene species mentioned above.

## VI. Tertiary and Recent Species of *CALOOSARCA*

### Anadara (Caloosarca) notoflorida H. E. Vokes, n. sp.

Plate 2, Figures 1-7, Text Figure 1i

1939 *Arca catasarca* Dall, Mansfield, Florida Geol. Surv. Bull. 18, p. 12 (dredged, Caloosahatchee River, 1 mile below Olga) (NOT p. 23, 32).

*Diagnosis:* Shell elongate, subrhomboidal, with moderately inflated, prosocoelus umbos located at or slightly anterior to the anterior fourth of the total length of the cardinal margin. Anterior end of the valve broadly rounded, passing gradually into the gently concave ventral edge, which is rather sharply rounded into the auriculate posterior end. The degree of auriculation varies, being usually most pronounced in the younger individuals, but the posterior margin is always more or less convex in its median portion and projecting in its dorsal segment. The cardinal margin is straight, but the dorsal margin of the main portion of the valve exterior to the cardinal area rises above it to form a rather sharp ridge, especially strong posterior to the umbos, giving the valves when viewed from their lateral aspects a distinctly higher posterior dorsal segment than the short anterior one. Surface of the valves ornamented by 21 to 24 (usually 22 to 23) relatively high radial ribs, which are rounded on top but almost straight-sided; the interspaces between them being approximately two-thirds as wide as the adjacent ribs, very gently concave, almost flat-bottomed, and subangulate at their lateral junctions with the ribs. Ribs on the anterior and median portions of the valve almost equal in width; those on the posterior becoming progressively somewhat lower and narrower, with interspaces of approximately equal width. Surface of the ribs and interspaces marked by rather elevated growth increments which occur at regular intervals and cause the tops of the ribs to appear to be nodulous.

The cardinal area is typical of the subgenus, straight and obscurely lozenge-shaped, widest immediately in front of the beaks. Ligament confined to the area posterior to the umbo in the earlier stages of development, appearing on the area anterior to the umbo only in large adult or gerontic specimens. Usually three to four, occasionally five, ligamental grooves (including the outer, marginal one) on the posterior portion prior to the appearance of any anterior one. Anterior end of the ligament in the earlier stages marked by a rounded groove extending transversely across the cardinal area from a point immediately beneath the umbo to a position directly above the junction of the anterior and posterior series of hinge teeth. Usually one or more short incipient transverse grooves anterior to this major one.

Hinge line straight, shorter than the length of the valve, with an anterior and a posterior series of relatively long and very narrow, markedly irregular teeth, generally transverse to the hinge line, but occasionally, especially toward the posterior end of the anterior series, tending to become oblique in position. At times adjacent teeth will unite for a portion of their length then divide to form two segments in a sort of parallel-sided "Y." The anterior series is always shorter than the posterior, usually with 18 to 20 teeth, but variations from 16 to 24 have been noted; the longer posterior series with

approximately two and one-half to three times as many teeth as the anterior one. Tooth counts on adult specimens reveal the following number of anterior/posterior teeth: 16/40, 18/47, 19/52, 20/45, 20/60, 21/51, 24/61. The anterior end of the posterior series is dorsal to the posterior end of the anterior one.

Interior of valve as in other species of the subgenus, with large well-marked adductor scars, the anterior one subtriangular in shape, the posterior more elongate, situated on a thickened smooth plate that is separated from the ventral side of the cardinal area and hinge plate by a distinct groove. Pedal retractor muscle scars moderately large, situated on the ventral side of the cardinal plate. Ventral margin strongly crenulated by the radial ribbing, the crenulations extending inward almost to the pallial line, inside of which are many shallow radial grooves.

*Discussion*: *Anadara* (*Caloosarca*) *notoflorida* occurs most abundantly in the Tulane University collections from three spoil bank localities that were bared during the course of the construction of the new trans-Florida highway extending from Naples to Fort Lauderdale—popularly known as "Alligator Alley." Mr. Druid Wilson of the United States Geological Survey loaned the writer specimens from the upper Miocene beds at Acline, Florida. The associated fauna at the Tulane localities also indicates an upper Miocene Pinecrest age for the species.

Although only a relatively few specimens were available for the present study, this species appears to be more stable and less variable in its general characters than are the succeeding forms referable to the subgenus *Caloosarca.* This feature is well shown in the rib counts. Fifty specimens reveal the following distribution:

| No. of ribs: | 21 | 22 | 23 | 24 | |
|---|---|---|---|---|---|
| No. of specimens: | | | | | |
| Right valves | 3 | 11 | 5 | 2 | = 21 |
| Left valves | 5 | 7 | 11 | 6 | = 29 |
| Total | 8 | 18 | 16 | 8 | = 50 |

This distribution over four rib number units may be contrasted with that observed for *rustica* (6), *crassicosta* (7), *aequalitas* (8), *catasarca* (9), and *notabilis* (6). It is interesting to note the increase in variability in this factor throughout the Pliocene and Pleistocene species, although the Recent *A. notabilis* proves less variable than its Pleistocene congeners.

*Comparison*: *Anadara* (*Caloosarca*) *notoflorida,* new species, most closely resembles *A.* (*C.*) *aequalitas* (Tucker and Wilson) in its overall aspect. It may be distinguished from that species, however, by its generally larger number of radial ribs, which are separated from each other by distinctly narrower interspaces. The valves tend to be more elongate in proportion to their height,

→

PLATE 2

Figures Page

*Anadara* (*Caloosarca*) *notoflorida* H. E. Vokes, n. sp. ---------- 13

1. USNM 645913 (paratype), left valve, length 74.8 mm, height 34 mm. Locality TU 797. Gerontic adult specimen, the largest in the collections.

2, 6, 7. USNM 645912 (holotype), left valve, length 49.4 mm, height 34 mm. Locality TU 797. 2. Exterior of left valve; 6. Anterior view of holotype; 7. Hinge and interior of holotype.

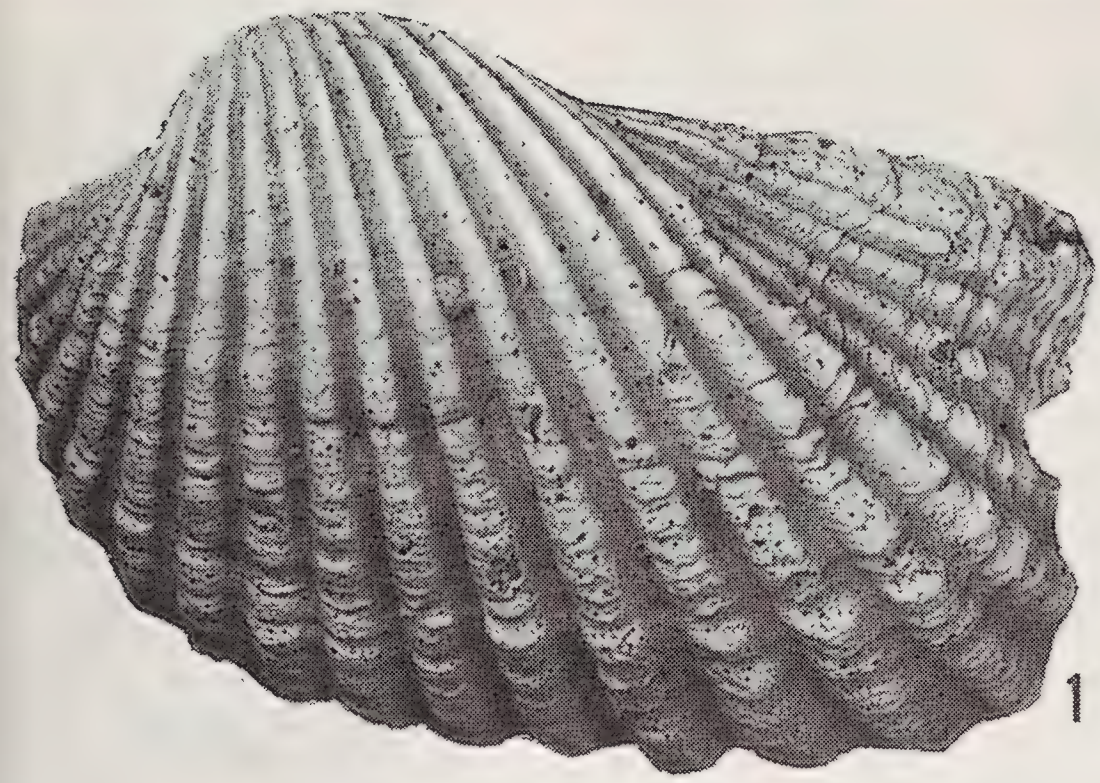
3. USNM 645914 (paratype), left valve, length 42.7 mm, height 31.8 mm. Locality TU 797.

4, 5. USNM 645915 (paratype), paired valves, length 38.3 mm, height 28 mm, diameter 28.2 mm. Locality TU 797. Dorsal view of conjoined valves; note smooth anterior end of cardinal plate. 5. Exterior view of right valve, note auriculate posterior extremity.

*Anadara* (*Caloosarca*) *hoerleae* H. E. Vokes, n. sp. ---------- 17

8, 9, 10. USNM 645916 (holotype), right valve, length 54.6 mm, height 41.7 mm. Locality TU 729. 8. Anterior view, compare with fig. 6; note stronger inflation and more enrolled umbos. 9. Exterior view, compare with figs. 2 and 3; note broader, heavier umbos and proportionately greater height. 10. Hinge and interior of holotype, compare with fig. 7; note narrower hinge plate with shorter, more regular teeth.

All specimens from Pinecrest Formation, upper Miocene, Florida. All figures approximately natural size.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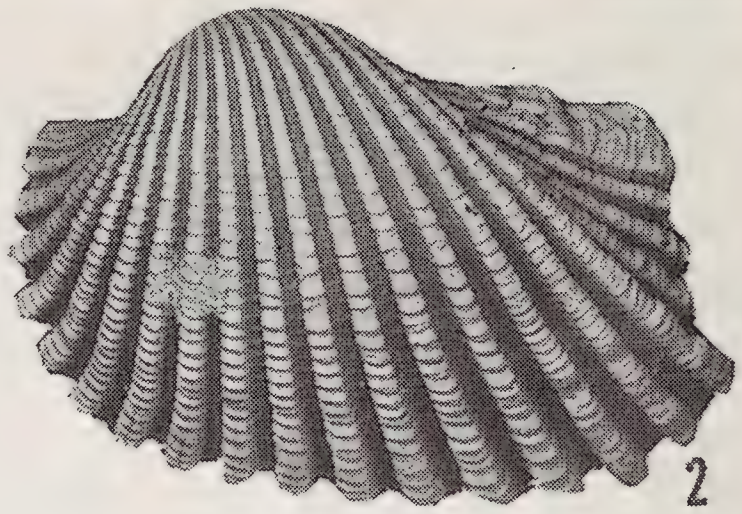
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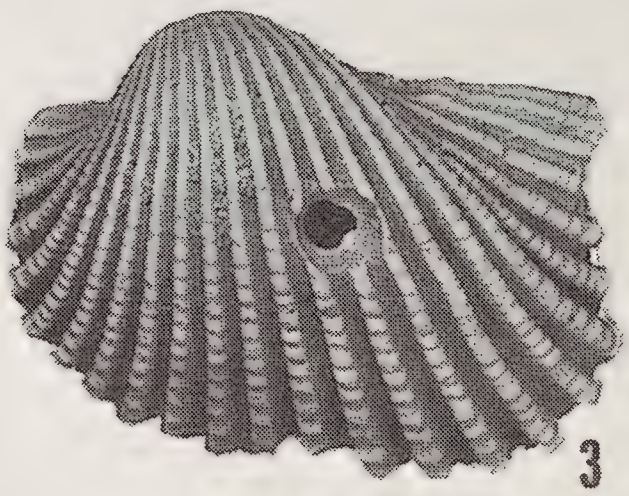
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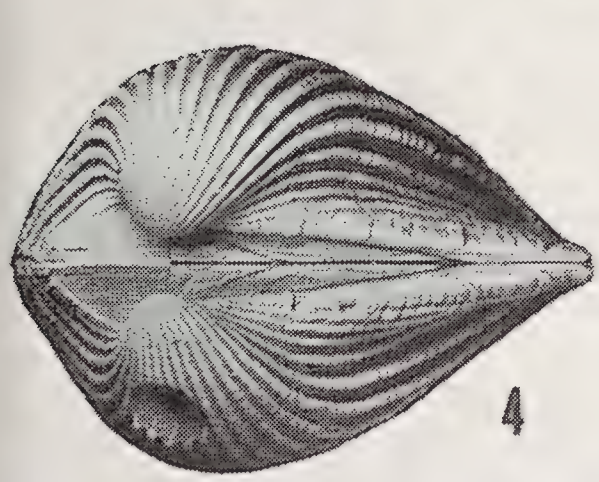
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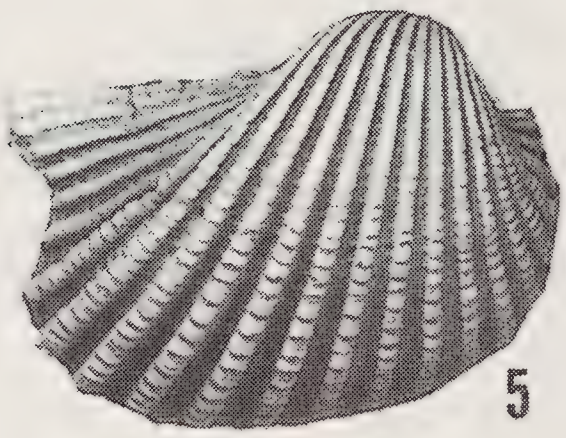
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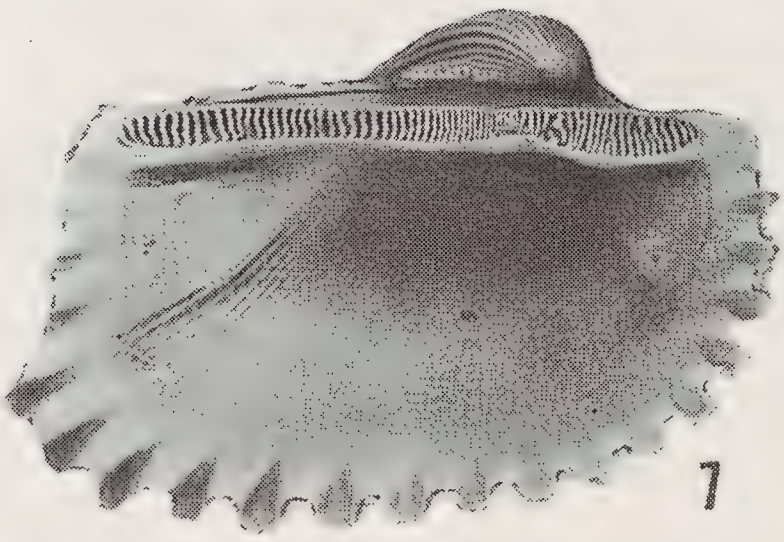
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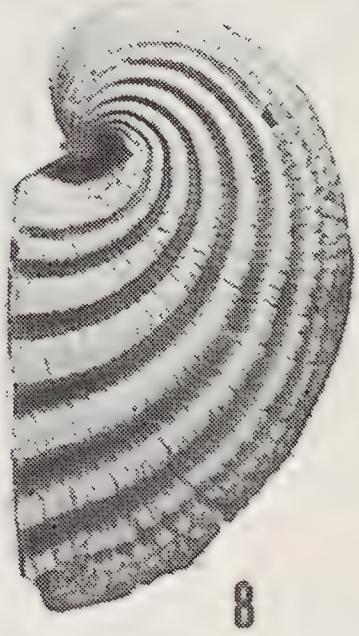
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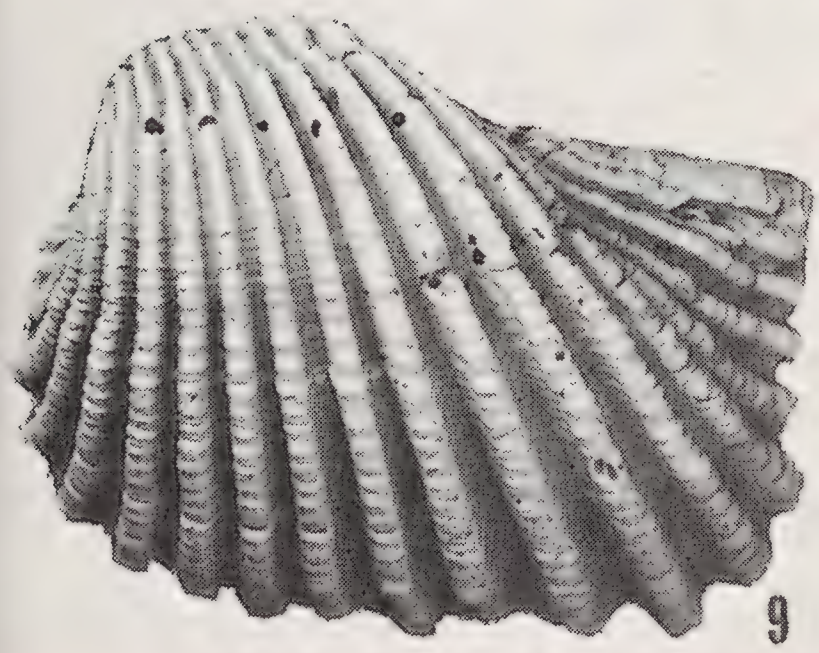
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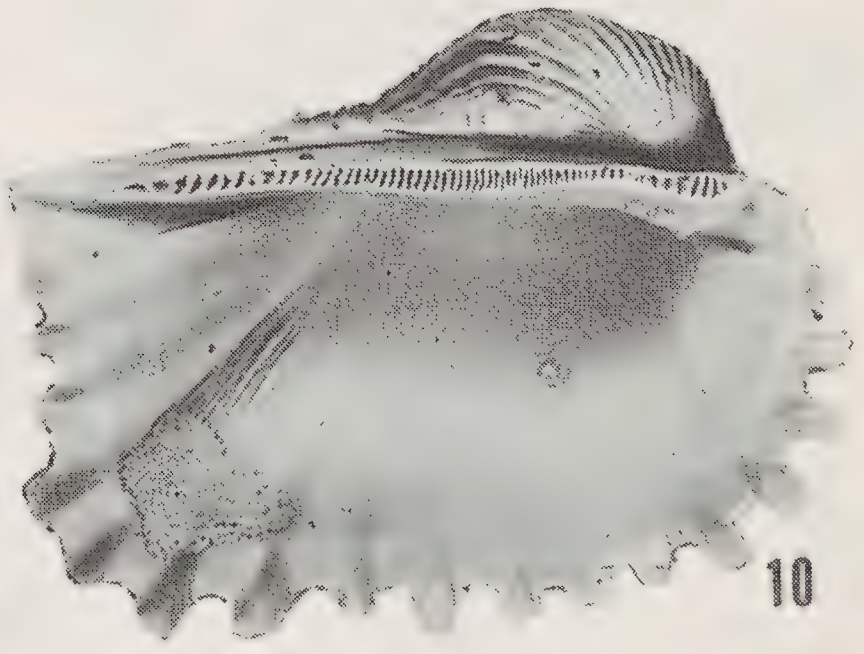
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PLATE 2

and the ventral margin less broadly convex than in *A. aequalitas.*

Some of the variants of *A. (C.) rustica* (Tuomey and Holmes) are superficially similar in general aspect, particularly in the immature stage of development, but none of the specimens of *A. notoflorida* have the ribs near the posterior umbonal ridge as strongly developed in contrast to those more anteriorly situated nor as high in proportion to their width as are those in the Waccamaw form. Furthermore, the ribs on the posterior portion of the valve are sharply delimited and straight-sided on both their dorsal and ventral edges, in contrast to the ventrally sloping sides of those present on *A. rustica.*

*Anadara (Caloosarca) crassicosta* (Heilprin) and *A. (C.) catasarca* (Dall) may readily be distinguished by the respective characteristics of the ornamentation in the two species. *A. (C.) notabilis* (Röding) differs in overall shape of the valves, number of ribs, and the fact that the ribs are much lower, lacking the straight sides that are so noticeable in *A. notoflorida.*

Holotype, USNM 645912: length 49.4 mm; height 34 mm; diameter (left valve) 17.3 mm. Locality TU 797.

Paratype, USNM 645913: length 74.8 mm; height 49.2 mm; diameter (left valve) 26.7 mm. The largest specimen in the collections. Locality TU 797.

Paratype, USNM 645914: length 42.7 mm; height 31.8 mm; diameter (left valve) 14.9 mm. Locality TU 797.

Paratype, USNM 645915: length 38.3 mm; height 28 mm; diameter (paired valves) 28.2 mm. Locality TU 797.

*Collections studied*: Tulane University localities 796, 797, 933; USGS 14075, 21257, 21907, 22298, 22299, 22445.

### Anadara (Caloosarca) hoerleae H. E. Vokes, n. sp.

Plate 2, Figures 8-10; Text Figure 1h

*Diagnosis:* Shell of average size for the subgenus *Caloosarca,* marked by broadly inflated and strongly enrolled umbos whose beaks are situated at or slightly anterior to the anterior fifth of the total length of the cardinal margin. Anterior margin of the valve broadly rounded and passing gradually into the almost straight ventral margin which, in turn, is rather sharply rounded into the auriculate to almost straight posterior margin. No young individuals are present in the available collection, but judging from the growth lines, the degree of posterior auriculation is most pronounced in the younger growth stages, as is characteristic of the subgenus. Cardinal margin straight, anteroposteriorly, but distinctly curved and rising laterally to the high dorsal margin of the main portion of the valve, which is exceptionally strong posterior to the umbos where it projects over the lateral portions of the cardinal surface. Surface of the valve ornamented by 21 to 23 relatively high radial ribs that are rounded on top and almost straight on their lateral margins. The interspaces between the ribs are approximately two-thirds as wide as the adjacent ribs, gently concave, almost flat-bottomed, and subangulate at their junctions with the ribbing. Ribs on the anterior end and the anterior and median portions of central area of the valve are almost equal in strength and width. The four or five ribs adjacent to the postero-ventral angulation are somewhat higher and broader, while the four or five on the posterior slope are lower and relatively narrower than those toward the anterior end. Surface of all ribs and interspaces are marked by rather elevated growth increments that occur at regular intervals and cause the tops of the ribs to appear to be nodulated.

Cardinal area essentially similar to that of other species of the subgenus, lozenge-shaped, widest anterior to the umbos and progressively narrowing posteriorly. However, the curved upper surface and the strong overhang of the main valve area results in the posterior portion, when viewed from above appearing to be rather narrow and almost linear. Ligament confined to the area posterior to the umbo throughout most of the development of the individual, appearing on the anterior portion only in late, gerontic stages. Anterior portion of the area with three or more shallow transverse grooves, the posteriormost of which extends from immediately below the beak to a position immediately above the junction of the anterior and posterior series of the hinge teeth.

Hinge line straight, shorter than the length of the cardinal area, with an anterior and a posterior series of transverse teeth. The anterior series is always shorter than the posterior, with 9 to 12 teeth that are usually relatively wider and stronger than the majority of the teeth in the posterior series. The longer posterior series has 57 teeth on the holotype specimen, the only one in the collection in which the entire toothrow is preserved. Its anterior end rides dorsally above the posterior end of the anterior series. The anterior four or five teeth of this series are relatively wide and strong, similar to those of the anterior series; the succeeding 35 to 40 teeth are erect and strikingly narrower and closer together, with the posteriormost teeth becoming again relatively wider and heavier and on the holotype tending to become somewhat irregular, usually with a distinct postero-ventral slope.

Interior of the valve typical of the subgenus. Anterior adductor large, separated from the ventral side of the hinge plate by a distinct groove, dorsal and ventral sides subparallel, slightly curved, the inner end broadly rounded. The posterior scar more elongate, also separated

from the ventral side of the hinge plate by a well-marked groove and somewhat undercut ventrally by a gutter-like depression that marks the inner side of the postero-ventral angulation. Pedal retractor scars moderately large, raised, and situated on the ventral side of the cardinal plate. Ventral margin strongly crenulated by the radial ribbing, the crenulations extending inward almost to the pallial line. The gutter-like depression ventral to the posterior adductor scar marked by irregular, elongate grooves. In two of the four specimens available, the inner margin of the pallial area is marked also by numerous short radial grooves.

*Discussion*: *Anadara* (*Caloosarca*) *hoerleae,* n. sp., is a rare form, represented in the collections only by four left valves from the upper Miocene deposits from the lower course of the Kissimmee River (locality TU 729). The associated fauna at this locality clearly indicates an upper Miocene, Pinecrest age for the species.

All specimens are strongly consistent in their general characteristics, including number of ribs, relative strength and shape of the ribs of the different areas of the valve surface, the strongly enrolled, inflated umbos, the curved surface of the cardinal area and the details of the varying strength of the hinge teeth. So far as can be determined from the small hypodigm available, there is less variability in these features in this species than in any other of the species here referred to the subgenus.

*Comparison*: In the characteristics of the surface ornamentation *A. hoerleae,* n. sp., is almost intermediate in position between *A. notoflorida,* n. sp., and the more regularly ribbed variants of *A. rustica* (Tuomey and Holmes). It may readily be distinguished from the former by its more anteriorly situated much more inflated and enrolled umbos (compare Plate 2, figures 6 and 8), more strongly developed ribs on the posterior umbonal area, its strongly curved cardinal area and the relatively narrower hinge with shorter anterior tooth series. The ribbing on the posterior end is heavier, and the ribs are broader, fewer in number and more sharply delimited, especially on their ventral slopes than are those of *A. rustica.* In that species the umbos are about equally as inflated as in the present form, but are situated somewhat more posteriorly, at or near the anterior fourth of the total length, and are not as strongly enrolled, the cardinal plate is not as notably curved, and the hinge series, while equally narrow as compared with that of *notoflorida,* differs in all details of the number and relative strength of the tooth elements present in the two series.

It gives me much pleasure to be able to dedicate this species to Mrs. Robert C. Hoerle of West Palm Beach, Florida, who collected the type specimens and donated them, together with a large collection of associated species to the paleontological collections of Tulane University.

Holotype, USNM 645916: Length 54.6 mm; height 41.7 mm; diameter (left valve) 21.0 mm. Locality TU 729.

Paratype, USNM 645917: Length 64.0 mm; height 42.0 mm; diameter (left valve) 23.3 mm. Locality TU 729.

*Collections studied*: Tulane University locality 729.

ANADARA (CALOOSARCA) new species?

1939 *Arca rustica* Tuomey and Holmes, MANSFIELD, Florida Geol. Surv., Bull. 18, p. 12 (dredged from Caloosahatchee River one mile below Olga).

1939 *Arca aequalitas* Tucker and Wilson, MANSFIELD, Florida Geol. Surv., Bull. 18, p. 12 (dredged from Caloosahatchee River one mile below Olga).

Material dredged from the bed of the Caloosahatchee River one mile below Olga, Lee County, Florida (USNM 14075) contains a specimen of *Anadara* (*Caloosarca*) *notoflorida,* new species, identified by Mansfield as *Arca catasarca* Dall, together with representatives of an undescribed species that Mansfield identified, in part, as *Arca rustica* Tuomey and Holmes and in part, as *Arca aequalitas* Tucker and Wilson. Mansfield recognized that this collection included material from more than one stratigraphic horizon, noting: "Some of the shells are clean and appear to have come from a sand (many of the shells are believed to be Pliocene); others from an indurated light gray limestone (probably also Pliocene); and others from a light tan argillaceous limestone (probably Buckingham limestone)." The specimen that is here identified with *A.* (*C.*) *notoflorida* is clean and white in color and apparently came from the sand unit. The specimens identified as *"Arca" aequalitas* and *rustica* all show adherent pieces or masses of a gray, lime-cemented shell sand and are presumed to have come from the "light gray limestone" unit. They cannot be identified with either of the two species to which Mansfield re-

ferred them, nor do they fall within the range of variation of any of the described species here recognized in the subgenus *Caloosarca.* In certain of the observable characters the form appears to be essentially intermediate in position between *Anadara* (*Caloosarca*) *hoerleae,* new species, and the Pliocene species *A.* (*C.*) *rustica* (Tuomey and Holmes) and *A.* (*C.*) *crassicosta* (Heilprin), but all specimens are worn, broken, or covered by the intractable limy matrix to the point that they comprise a hypodigm that is not adequate for formal description.

The ribs upon the anterior end and the anterior portion of the median part of the valve are similar in general to those that may be observed in *A.* (*C.*) *hoerleae* and *A.* (*C.*) *rustica,* while those on the posterior portion of the median area are quite like those of *A. rustica* in being somewhat broader and higher than those more anterior in position, but do not approach the extreme width presented by the posterior ribs of *A. crassicosta* (Heilprin) [= *rustica* of earlier Florida students]. The ribbing on the posterior end of the valve is similar to that on *A. hoerleae* and *A. crassicosta* in being as sharply raised on the ventral sides of the ribs as on the dorsal sides, a feature that contrasts with development of these ribs on specimens of *A. rustica.* Two of the three specimens upon which the number of ribs may be determined show but 20 ribs, the third has 24. None of the 45 specimens of *A. rustica s.s.* upon which the number of ribs could be determined had as few as 20 ribs, while none of the 200 specimens of *A. crassicosta* that were used in determining the range of rib number variation in that species had as many as 24. Thus in this character also, these specimens appear to occupy a position more or less intermediate between *A. hoerleae* and the two Pliocene species.

On the other hand the valves differ from those of all three species mentioned above in general proportions, being considerably more elongate relative to valve height, with lower and less inflated umbos that are more like those present in *A.* (*C.*) *notoflorida,* new species (see Pl. 6, fig. 6).

Material examined: USGS loc. 14075.

### Anadara (Caloosarca) rustica (Tuomey and Holmes)

Plate 3, Figures 1-9; Text Figures 1f, g.

1857 *Arca rustica* Tuomey and Holmes, Pleiocene Fossils South Carolina, p. 39, pl. 15, fig. 1 (described, "Waccamaw").

1863 *Scapharca* (*Arca*) *rustica* Tuomey and Holmes, Conrad, Acad. Nat. Sci., Phila.,

→

## Plate 3

Figures

*Anadara* (*Caloosarca*) *rustica* (Tuomey and Holmes) ---------- 18

1. USNM 645918, left valve, length 74 mm, height 54 mm. Locality TU 558. Exterior view of gerontic left valve; ribs on posterior portion of median area of valve are but slightly wider than those immediately anterior, but have noticeably wider interspaces.

2, 8. USNM 645920, right valve, length 53.7 mm, height 44 mm. Locality TU 558. 2. Exterior view of valve with ribbing similar to that found in *A.* (*C.*) *crassicosta* (Heilprin). 8. Hinge view of same specimen.

3. USNM 645921, right valve, length 50.6 mm, height 41 mm. Locality TU 558. Exterior view of strongly auriculate specimen with posterior ribbing but slightly stronger than that on the more anterior part of valve.

4, 5, 9. USNM 645919, right valve, length 66.9 mm, height 52.6 mm. Locality TU 558. 4. Exterior view; 5. Hinge and interior of valve; 9. Dorsal view.

6. USNM 645922, right valve (× 1½), length 25 mm, height 16 mm. Locality TU 558. Strongly auriculate immature right valve with wide ribs on posterior half of median portion of valve.

7. USNM 645923, left valve (× 1½), length 21.8 mm, height 16 mm. Locality TU 558. Auriculate immature left valve with ribbing of almost equal strength over entire valve surface.

All specimens from Waccamaw Formation, Pliocene, at Crescent Beach, South Carolina, airport. All figures, except 6 and 7, of approximately natural size.

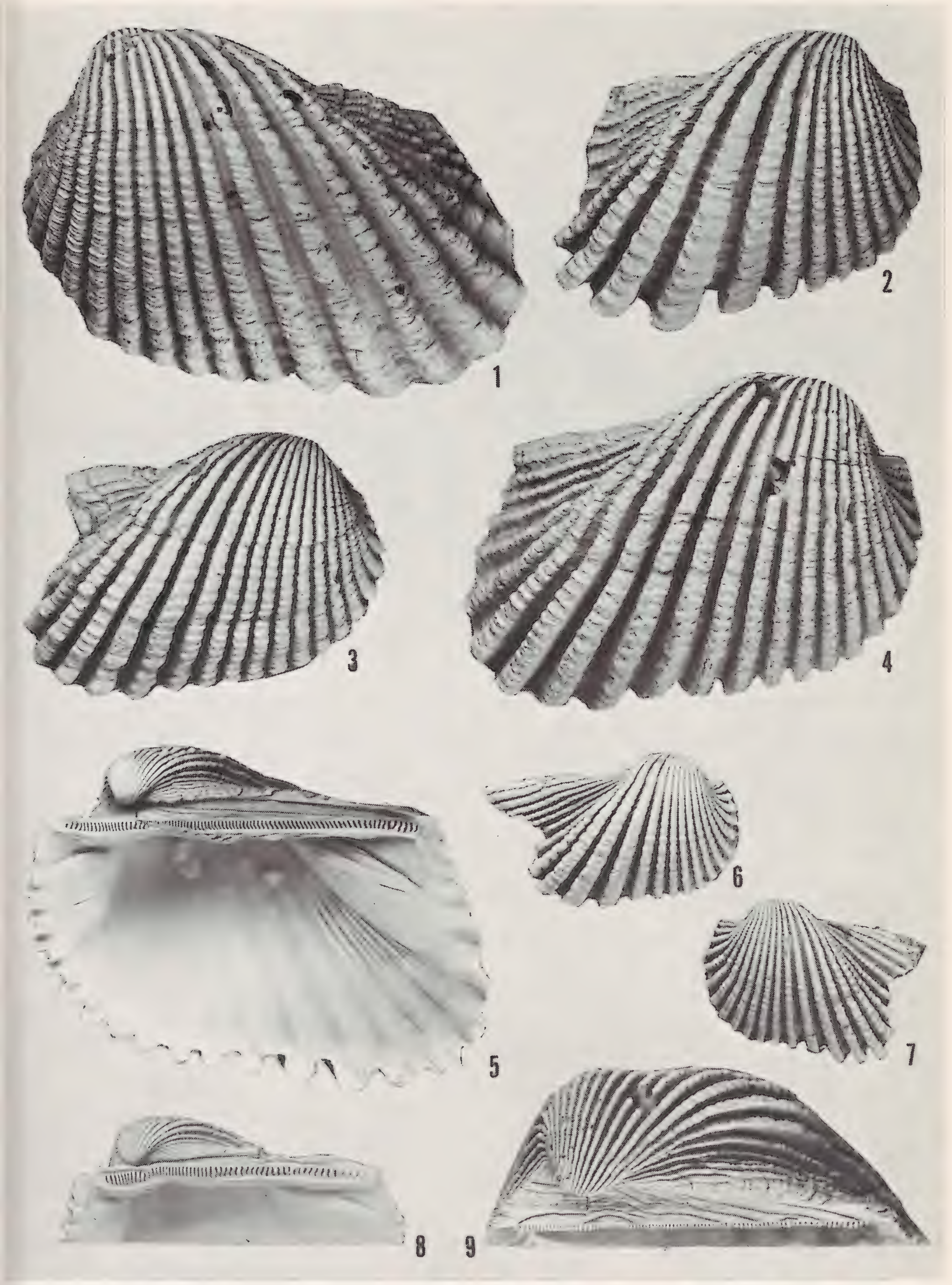



PLATE 3

Proc. for 1862, p. 580 (listed, Miocene [sic] fossils of Atlantic Slope).

1898 *Scapharca* (*Anadara*) *rustica* Tuomey and Holmes, DALL, Trans. Wagner Free Inst. Sci., vol. 3, pt. 4, p. 653 (part, NOT pl. 31, figs. 6, 9) (*A. crassicosta* Heilprin placed in synonymy).

1912 *Arca rustica* Tuomey and Holmes, MILLER in W. B. Clark, *et al.*, North Carolina Geol. and Econ. Survey, vol. 3, pt. 1, p. 256 listed (Neill's Eddy Landing), 257 (Walker's Bluff), 323 & 324 (Waccamaw Formation).

1916 *Arca rustica* Tuomey and Holmes, SHELDON, Paleont. Americana, vol. 1, no. 1, p. 55 (part, NOT pl. 13, figs. 4, 5).

1937 *Arca rustica* Tuomey and Holmes, MANSFIELD AND MACNEIL, Jour. Wash. Acad. Sci., vol. 27, no. 1, p. 9 (Intercoastal Waterway near Little River, South Carolina).

1961 *Anadara* (*Caloosarca*) *rustica* (Tuomey and Holmes), OLSSON, Panamic-Pacific Pelecypoda, p. 98 (type of *Caloosarca*, n. subgen.) [South Carolina record only].

1962 *Anadara rustica* (Tuomey and Holmes), DUBAR, Geologic Notes, South Carolina Div. Geol., vol. 6, no. 3, p. 28 (listed Waccamaw Formation, North and South Carolina).

1963 *Anadara rustica* (Tuomey and Holmes) DUBAR AND HOWARD, Southeastern Geol., vol. 5, no. 1, p. 36, 63 (listed, Waccamaw Formation, Horry Co., South Carolina).

1964 *Anadara* (*Caloosarca*) *rustica* (Tuomey and Holmes), OLSSON AND PETIT, Bull. Amer. Paleontology, vol. 47, p. 527, pl. 77, figs. 4, 4a, 4b.

1965 *Anadara rustica* Tuomey and Holmes, DUBAR AND FURNBUNCH, Geol. Notes, South Carolina Div. Geol., vol. 9, no. 1, p. 22 (listed, Waccamaw Formation, Intercoastal Waterway, Horry Co., South Carolina).

The original description of Tuomey and Holmes, inadequate and based upon very imperfect material, was as follows:

"*A. testa crassa, sub-quadrata, radiatim costata; costis sub-squamosis; latere buccali brevioribus, costis crenatis; latere anali carinato, angulato, truncato, costis majoribus; umbonibus inter se fere contingentibus.*

"DESCRIPTION. Shell thick, somewhat square, radiately, and unequally ribbed; ribs almost squamose; buccal side very short, ribs crenate; anal side carinate, angular, truncate, ribs very large; ligament area narrow, umbones nearly touching.

"This fossil is readily distinguished by the coarse ribs and deeply excavated interspaces on the anal side. The margin is strongly crenulated. Only a single perfect valve has been found, with a fragment of a larger individual which is presented in Fig. 1.

"PLATE XV., FIG. 1. *Fragment of the only specimen in our possession. The outline is correct. A perfect shell, though much smaller, was lost after the outline of Fig. 1 had been taken.*

"LOCALITY. Waccamaw."

As earlier noted, the species has been rare in collections previous to the dredgings at the Crescent Beach, South Carolina, airport. This plus the inadequate nature of the original material has resulted in confusion as to the limits of the species. Dall's action (1898, p. 653) placing the Caloosahatchee species *A. crassicosta* Heilprin in synonymy with the present form, while obviously a result of the inadequate knowledge of *A. rustica* at the time, nevertheless was peculiarly unfortunate in that *A. crassicosta* is abundant in the collections and *A. rustica* became identified primarily on the basis of the characters exhibited by the Florida species.

Olsson and Petit (1964, p. 527) add the following supplementary descriptive notes:

"The shell becomes large and heavy at maturity, the umbones and beaks near the anterior one-fourth, the posterior side showing a tendency to become winged and is often deeply sinuated especially in the juvenile stage, while the umbones become more or less sulcated along the middle. The ribs number about 18 from the anterior slope to the umbonal angle, and about six more on the posterior slope, the anterior and middle ones are large, high, and coarsely noded, as narrow as their interspaces, except those along the umbonal slope which are somewhat larger; the posterior set becomes progressively smaller towards the [dorsal] margin. In small specimens, the cardinal area is narrow behind the beaks and bears a few ligamental lines, the space anterior and under the beaks bare. In the larger gerontic specimens, the cardinal area may be high and completely covered with ligamental lines, only a small space under the inrolled, prosogyrate beaks remaining bare. The ventral margin is deeply fluted by the ends of the external ribs."

Forty-five relatively complete valves, 21 right and 24 left, plus a few fragmentary specimens were available for the present study. It is of interest to note that 18 of the right valves and 20 of the left ones are from the Crescent Beach airport locality; all other Tulane collecting had yielded but seven valves. A count of the number of ribs in these specimens shows the following distribution:

| No. of ribs: | 22 | 23 | 24 | 25 | 26 | 27 | |
|---|---|---|---|---|---|---|---|
| No. of specimens: | | | | | | | |
| Right valves | 3 | 1 | 8 | 7 | 1 | 1 | = 21 |
| Left valves | 1 | 5 | 8 | 7 | 3 | 0 | = 24 |
| Total | 4 | 6 | 16 | 14 | 4 | 1 | = 45 |

The ribs on the anterior half of the valve, including the anterior end, are round-topped, rather coarsely noded, higher than wide, and straight-sided, separated by flat-bottomed interspaces that are slightly narrower than the adjacent ribs (see Text fig. 1f).

The junction of the rib base with the interspace is very sharply rounded, almost forming a 90 degree angle. The most posterior rib in this series tends to be a little more strongly developed than the rest and usually is followed, posteriorly, by four or five ribs that ornament the posterior half of the median area of the valve, the posterior umbonal ridge and on to the posterior end of the valve. The posterior umbonal ridge usually occurs approximately at the position of the fourth, or between the third and fourth of these ribs. They constitute the most variable portion of the ornament. In the majority of the specimens they differ from the ribs of the more anterior series primarily in size, agreeing in all relative proportions with the relationship of rib height to width, and of width of rib to that of the adjacent interspaces. In some of the specimens (Plate 3, figs. 3 and 4) the size difference is not great and the resultant ornament superficially resembles that of *Anadara* (*Caloosarca*) *aequalitas* (Tucker and Wilson) and *A.* (*Caloosarca*) *hoerleae,* new species. In the majority of specimens, however, there is a noticeable difference, and one extreme, a right valve with 22 ribs (Plate 3, fig. 2) even has the anterior two or three ribs of this series noticeably wider than their interspaces, more or less undercut on their sides, especially the anterior one, and as a result comes to have a rather close resemblance to *A.* (*Caloosarca*) *crassicosta* (Heilprin).

*A. rustica* may, however, be readily separated from both of the above named species by the nature of the ribbing on the posterior end of the valve. In this area on mature specimens the rib that immediately follows the stronger ones adjacent to the umbonal ridge is usually rather similar to these, being stronger than any of those postero-dorsal to it but agrees with them in having a distinctly sloping antero-ventral side and a straight to undercut postero-dorsal slope. Immature specimens tend to have well-developed, raised, noded ribs on this area that are, with the exception of one or two ribs immediately adjacent to the dorsal margin, usually only about one-half as wide as their adjacent interspaces; the dorsally situated ribs may be slightly wider than the interspace between them. In adult specimens, however, the majority of the ribs tend to lose their strength and to assume the appearance of irregular, noded threads, asymmetrical in section with a distinct antero-ventral slope and a steep postero-dorsal one. In both *A. aequalitas* and *A. crassicosta* these posterior ribs maintain their identity, their sides being essentially vertical in all but the most gerontic specimens. Furthermore, the ribs on the median portions of the valves of *A. rustica* are much higher in proportion to their width than are those of either of the two other species (see Text fig. 1).

The umbones are well inflated, the beaks rounded and prosogyrate, situated well in front of the anterior fourth of the total length, usually about at the anterior fifth in average specimens, but often are as far forward as the anterior sixth of the total length in large, gerontic forms. The cardinal area is broad, widest immediately under the anteriorly situated beak. The dorsal margin of the valve distinctly curves over and above the outer margin of the ligamental area posterior to the umbo but does not project anterior to that structure. The result is that the area appears to be much narrower posterior to the umbos than anterior to them. The ligament was confined to the area posterior to the umbo during the earlier stages of growth. It was inserted in a rather deep groove at the outermost edge of the cardinal area and appears to have completely covered the portion posterior to the umbones at all stages of growth. The portion anterior to the umbones was free of ligament during the period up to relative maturity but was invaded by that structure in later stages. Diagonally situated ligamental grooves, more or less parallel with the outer margin of the cardinal area, mark the posterior portion of that structure during the interval when the ligament was wholly posterior in position. These tend to become irregular chevrons when the ligament is also present on the anterior portion of the area. Of the 14 larger specimens with chevron-shaped grooves on the inner margin of the area, 4 have three diagonal posterior grooves before the appearance of any anterior limb, 5 have four, and another 5 have five such grooves. Five specimens show four posterior grooves with no trace of any anterior grooving. All of the specimens show a narrow, linear depressed

line trending more or less transversely across the cardinal area from a position immediately beneath the umbone. The posteriorly situated ligamental grooves terminate at this line, and when chevrons are developed, the apex of the chevron angle occurs there. Presumably this marks the anterior edge of the ligament during the period when this structure was confined to a position behind the beaks. The groove is not strictly transverse in position, showing a slight tendency to move more anteriorly as the beaks assume a relatively more anterior position.

The hinge line is straight, with the teeth in two series that meet approximately at the position of the transverse groove noted above, with the posterior series thus being much longer than the anterior one, its anterior end being located dorsal to the posterior end of the anterior series. In very large gerontic specimens this separation into series may become obscured. The number of teeth in each series is variable. A count of the teeth in each gave the following numbers of anterior/posterior teeth: 11/29; 13/38; 13/44; 14/48; 17/59; 17/64; 18/53; 18/58; 22/71. The individual teeth are usually narrow and transverse to the hinge plate. Variation, when present, tends to occur near the posterior end of the longer series, and in most cases is indicated by the development of broadly chevron-shaped teeth that have the apex of the chevron pointed posteriorly. In some gerontic specimens the posterior teeth may break down to form small nodose denticles; these appear at times to represent the dorsal and ventral ends of chevrons in which the median apex has failed to develop.

The anterior and posterior adductor scars are prominent and relatively large, the posterior being situated on an elongately thickened platform that has a relatively narrow but well-marked channel dorsal to it, separating it from the projecting ventral side of the cardinal margin. This latter area bears four or more rather well-defined diductor and pedal retractor muscle scars.

Figured Specimen, USNM 645918: length 74 mm; height 54 mm; diameter (left valve) 29.6 mm. Locality TU 558.

Figured Specimen, USNM 645919: length 66.9 mm; height 52.6 mm; diameter (right valve) 25 mm. Locality TU 558.

Figured Specimen, USNM 645920: length 53.7 mm; height 44 mm; diameter (right valve) 19.4 mm. Locality TU 558.

Figured Specimen, USNM 645921: length 50.6 mm; height 41 mm; diameter (right valve) 19.4 mm. Locality TU 558.

Figured Specimen, USNM 645922: length 25 mm; height 16 mm; diameter (right valve) 7.3 mm. Locality TU 558.

Figured Specimen, USNM 645923: length 21.8 mm; height 16 mm; diameter (left valve) 7 mm. Locality TU 558.

*Distribution*: Tulane University localities 558, 559, 870. USGS localities, 4276 (Neill's Eddy Landing), and Tilly's Lake, Waccamaw River. Waccamaw Formation, North and South Carolina.

## ANADARA (CALOOSARCA) CRASSICOSTA (Heilprin)

Plate 4, Figures 1-7; Text Figure 1e

1887 *Arca crassicosta* HEILPRIN, Trans. Wagner Free Inst. Sci., vol. 1, p. 96, pl. 13, figs. 30, 30a (described, Caloosahatchee River).

1895 *Arca crassicosta* Heilprin, DANA, Man. Geology, ed. 4, p. 900, fig. 1508.

1898 *Scapharca* (*Anadara*) *rustica* Tuomey and Holmes, DALL, Trans. Wagner Free Inst. Sci., vol. 3, pt. 4, p. 653 (part) (?, pl. 31, figs. 6, 9) (*crassicosta* placed in synonymy).

1916 *Arca rustica* Tuomey and Holmes, SHELDON, Paleont. Americana, vol. 1, no. 1, p. 55 (part), pl. 13, figs. 4, 5. (Dall's discussion reprinted; figured from Shell Creek, Fla.)

1929 *Arca rustica* Tuomey and Holmes, COOK AND MOSSOM, Florida Geol. Survey, 20th Ann. Rept., p. 156, pl. 9, fig. 1. (Caloosahatchee Marl).

1939 *Arca rustica* Tuomey and Holmes, MANSFIELD, Florida Geol. Survey, Bull. 18, p. 18 (3/4 mi. above Fort Denaud), 24 (Myakka River), 27 (Caloosahatchee Fauna).

1945 *Anadara rustica* (Tuomey and Holmes), COOK, Florida Geol. Survey Bull. 29, p. 216, fig. 28(1) (characteristic of Caloosahatchee Marl).

1953 *Anadara* (*Anadara*) *rustica* (Tuomey and Holmes), OLSSON AND HARBISON, Acad. Nat. Sci., Phila., Mon. 8, p. 37, pl. 3, figs. 1, 1a. ("Common at St. Petersburg and most other Pliocene localities in Florida.")

1958 *Anadara* (*Anadara*) *rustica* (Tuomey and Holmes), DUBAR, Florida Geol. Survey, Bull. 40, p. 156 (part), pl. 1, fig. 9 (NOT figs. 2, 3). ("Common in the Caloosahatchee formation.")

1962 *Anadara rustica* (Tuomey and Holmes), DUBAR, Florida Geol. Survey, Bull. 43, p. 23, 26 (listed, Shell Creek), 34 (listed, Alligator Creek), 40 (listed "Pliocene" and "Caloosahatchee"), 60 (general faunal list).

1964 *Anadara* (*Caloosarca*) *crassicosta* (Heilprin), OLSSON AND PETIT, Bull. Amer. Pale-

ontology, vol. 47, p. 520 (Caloosahatchee fauna), 528 (removed from synonymy of *A. rustica*).

1965 *Anadara* (*Cara*) *rustica* (Tuomey et Holmes, 1857), Glibert and van de Poel, Inst. Roy. Sci. Nat. de Belgique, ser. 2, fasc. 77, p. 53 (Pliocene, Shell Creek, "De Soto Co." [= Charlotte Co.] Florida, U.S.A.).

1968 *Anadara crassicosta* Heilprin, Olsson, Miami Geol. Soc., Guidebook, 2nd. Ann. Field Trip, pl. 2, fig. 8 (index fossil for Caloosahatchee Formation).

Heilprin's original description of this species was as follows:

"Shell subquadrangular, ventricose, ponderous, ornamented with about twenty, coarse, elevated, transversely barred, terete ribs, which are somewhat irregular and crowded on the anterior half of the shell, becoming widely separated and profoundly elevated on the posterior half; beaks nearly anterior, looking forward, separated from each other by a fairly broad interval; hingeline almost as long as the greatest length of the shell, pectinated with numerous, narrow, nearly vertical teeth; ligamental area narrow, elongated, with about six longitudinal lines, which rise toward the apex of the beak; interior of the shell coarsely rugated; base ascending anteriorly, profoundly crenated.

"Length, 2.7 inches: height, two inches."

Heilprin was not absolutely certain that his species was indeed distinct from Tuomey and Holmes' *A. rustica,* stating that: "It closely resembles *Arca rustica* of Tuomey and Holmes . . . and may, indeed, be that shell. . . . Their figure, drawn from a mere fragment, does not represent the profound ribs seen in the Florida fossil; the posterior interspaces are apparently also much narrower, nor does there appear to be any marked variation either in the disposition or the size of the costae. Still, the differences here indicated, which are based upon figure and description only, may be more apparent than real, and the two forms, as above intimated, may in reality represent a single species. . . . " As earlier noted, it was Dall who synonymized *A. crassicosta* with *A. rustica,* leading to the misinterpretation that has been prevalent concerning these two forms. And, it may be noted, that the specimen figured by Dall as from the "Caloosahatchee beds" is not a typical representative of *A. crassicosta* as developed in the Caloosahatchee Formation, but appears to be a variant towards *A. aequalitas* (Tucker and Wilson). The distinctive characters given by Heilprin are yet valid in the separation of *A. rustica* and *A. crassicosta.*

In general, typical specimens of *A. crassicosta* have fewer radial ribs than are to be found on typical forms of *A. rustica* (see table 1). A count of the ribbing on 200 specimens (100 right and 100 left valves) of *A. crassicosta* reveals the following distribution:

| No. of ribs: | 17 | 18 | 19 | 20 | 21 | 22 | 23 | |
|---|---|---|---|---|---|---|---|---|
| No. of specimens: | | | | | | | | |
| Right valves | 1 | 13 | 37 | 35 | 11 | 2 | 1 | = 100 |
| Left valves | 0 | 9 | 43 | 37 | 10 | 1 | 0 | = 100 |
| Total | 1 | 22 | 80 | 72 | 21 | 3 | 1 | = 200 |

A comparison of these counts with those made, of fewer specimens, for *A. rustica* shows that while the majority of the specimens of *A. crassicosta* have 19 or 20 ribs, the majority in *A. rustica* have 24 or 25. There is, it is true, a slight overlapping in the 22 to 23 rib range, however, only a few specimens in each species group fall into this interval and these may be rather easily separated on other grounds. Typical forms of *A. rustica* may be distinguished by the fact that in that species the interspaces between the ribs are deeper than they are in *A. crassicosta,* the ribbing along the region of the posterior umbonal slope is not as strikingly delimited from that on the more anterior portions of the valve, and the radials on the posterior end of *A. crassicosta* are persistent as defined ribs well delimited from their interspaces, not reduced in strength with sloping anteroventral margins such as are to be found in true *A. rustica.*

There is considerable variation in the relative height/length proportions of the valves as well as in the degree of inflation in the umbonal region. In general those specimens with a high inflated umbone tend to be relatively shorter and more quadrate in outline when viewed from the hinge side than are those with less inflated, and hence lower, umbones (compare figs. 4 & 5, Plate 4).

The basic features of the ligamental structure are the same as those discussed for *A. rustica.* The principal differences in the cardinal area lie in the tendency for the ligamental grooves to be more irregularly developed and in general more numerous in the present species, with, as a result, a larger number of grooves posterior to the umbo prior to the first appearance of the anterior grooving to form the true chevron-shaped structures. Of 20 specimens counted, only one had as few as 3 posterior grooves before the appearance of the chevron; 9

specimens had four grooves; 5 had five, 4 had 6, and one particularly gerontic looking specimen had eight posterior grooves with no trace of any on the anterior end.

Similarly, the hinge structures appear to be basically the same in the two species. The anterior and posterior tooth series are well delimited, with the anterior end of the posterior series passing dorsally above the posterior end of the anterior one and reaching a point coincident with the termination of the transverse groove on the hinge plate that marked the anterior end of the fibrous ligamental structure. The number of teeth in the two series are equally as variable in *A. crassicosta* as they are in *A. rustica* and the principal difference between the species appears to lie in the fact that in the former it is the teeth of the anterior series that are most subject to variation, often breaking down into small denticles situated near the dorsal and ventral sides of the toothrow, with the adjacent teeth of the opposite valves often bridging across the intervening socket to form a somewhat crude "H" structure. While this same tendency has been noted to occur sporadically along the posterior tooth series, it is never as commonly developed in this area as it is among the teeth of the anterior series.

The nature and position of the adductor and diductor scars is the same as that to be observed in *A. rustica*, as are the other features of the interior of the valves.

*Distribution*: *Anadara crassicosta* appears to be confined to the fauna of the Caloosahatchee Marl as restricted by Olsson and Petit (1964, p. 519) to the strata below the *Crassostrea virginica labellensis* Olsson and Harbison zone. It is abundant at almost all Caloosahatchee localities. A few specimens occur in spoil bank collections from Levee 28 in the western part of Broward County, Florida, associated with a fauna that is dominated by Pinecrest species. Since these are spoil bank collections, however, it is probable that a thin remnant of Caloosahatchee strata overlies the upper Miocene in this area.

Figured Specimen, USNM 645924: length 69.7 mm; height 56.7 mm; diameter (right valve) 29.6 mm. Locality TU 767.

Figured Specimen, USNM 645925: length 57 mm; height 46.1 mm; diameter (paired valves) 48.5 mm. Locality TU 767.

Figured Specimen, USNM 645926: length 25.2 mm; height 17.1 mm; diameter (paired valves) 14.6 mm. Locality TU 767.

Figured Specimen, USNM 644317: length 58.3 mm; height 48.1 mm; diameter (left valve) 26.3 mm. Locality TU 975.

*Collections studied*: Tulane University localities 79, 202, 203, 519, 523, 527, 529, 532, 536, 539B, 541, 579, 583, 736, 740, 741, 742, 749, 755, 767, 768, 770, 792, 801, 802, 816, 975; USGS 23722.

### Anadara (Caloosarca) aequalitas (Tucker and Wilson)

Plate 5, Figures 1-8; Text Figure 1c,d

→

## Plate 4

Figures Page

*Anadara (Caloosarca) crassicosta* (Heilprin) ..... 22

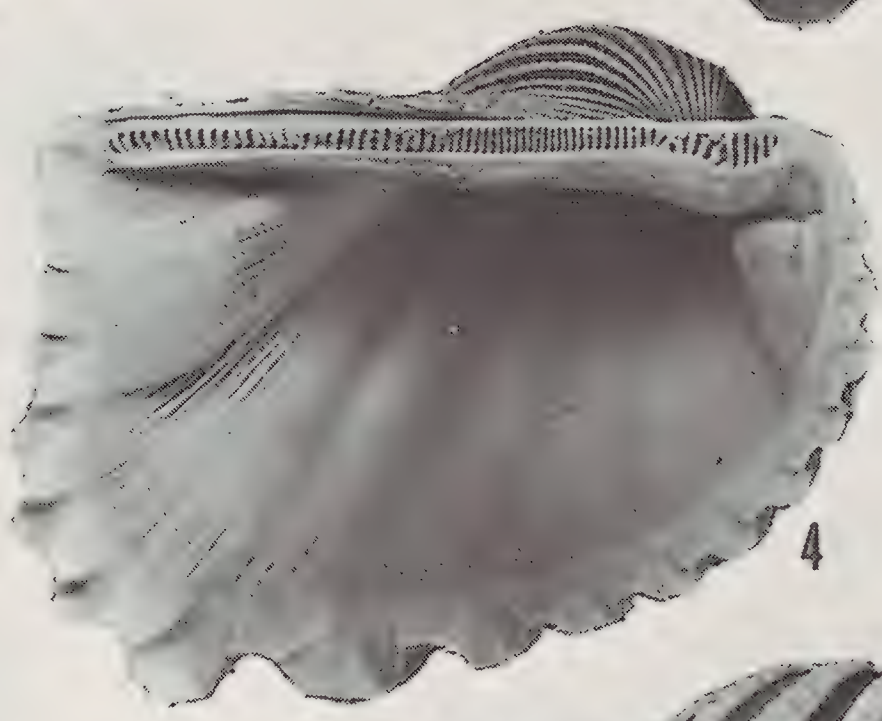
1. USNM 645924, right valve, length 69.7 mm, height 56.7 mm. A large, somewhat gerontic specimen. Locality TU 767.

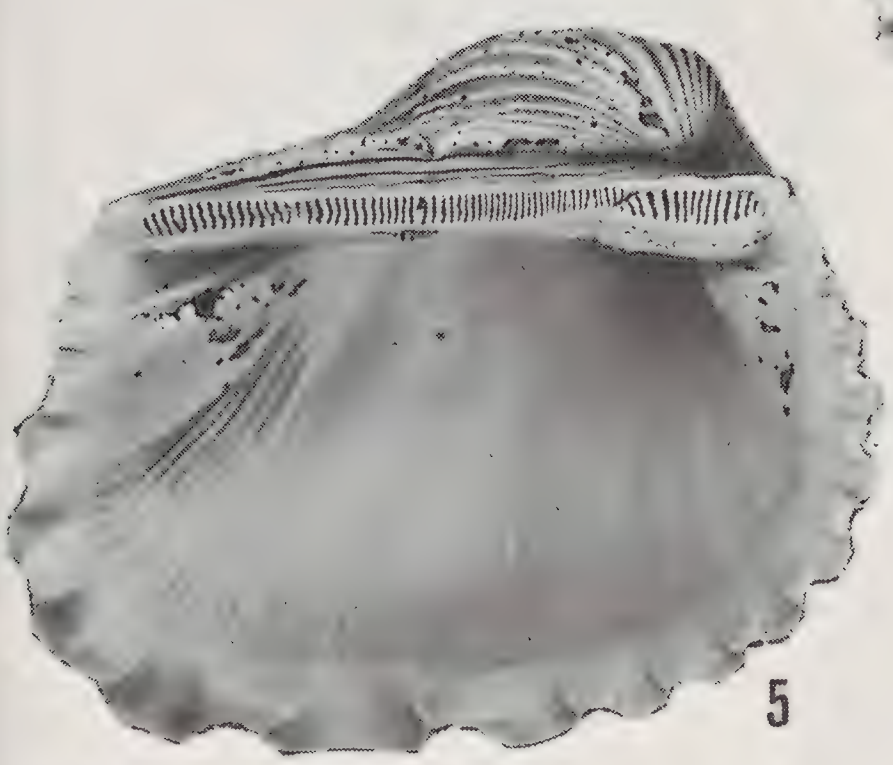
2, 4, 6, 7, 8. USNM 645925, paired valves, length 57 mm, height 46.1 mm, diameter 48.5 mm. Locality TU 767. 2. Exterior, left valve; 4. Hinge and interior, left valve; 6. Exterior, right valve; 7. Dorsal view, conjoined valves; 8. Ventral view, conjoined valves.

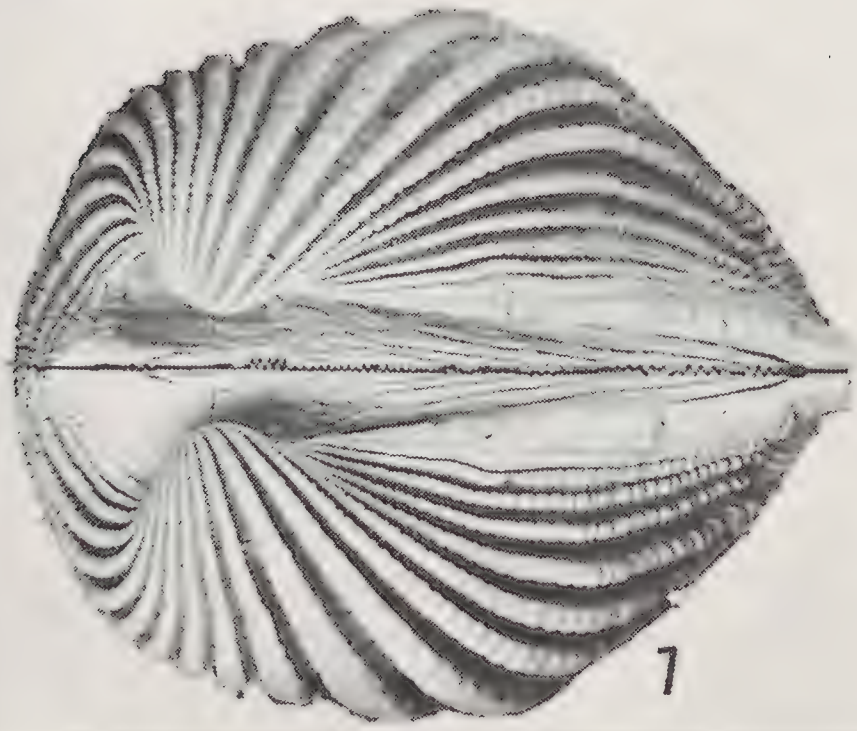
3. USNM 645926, left valve, length 25.2 mm, height 17.1 mm. Locality TU 767. Exterior, left valve to show strongly auriculate immature stage.

4. USNM 644317, left valve, length 58.2 mm, height 48.1 mm. Locality TU 975. Specimen with strongly inflated umbone; note more quadrate outline of valve.

All specimens from Caloosahatchee Formation, Pliocene, of Florida. All figures approximately natural size.





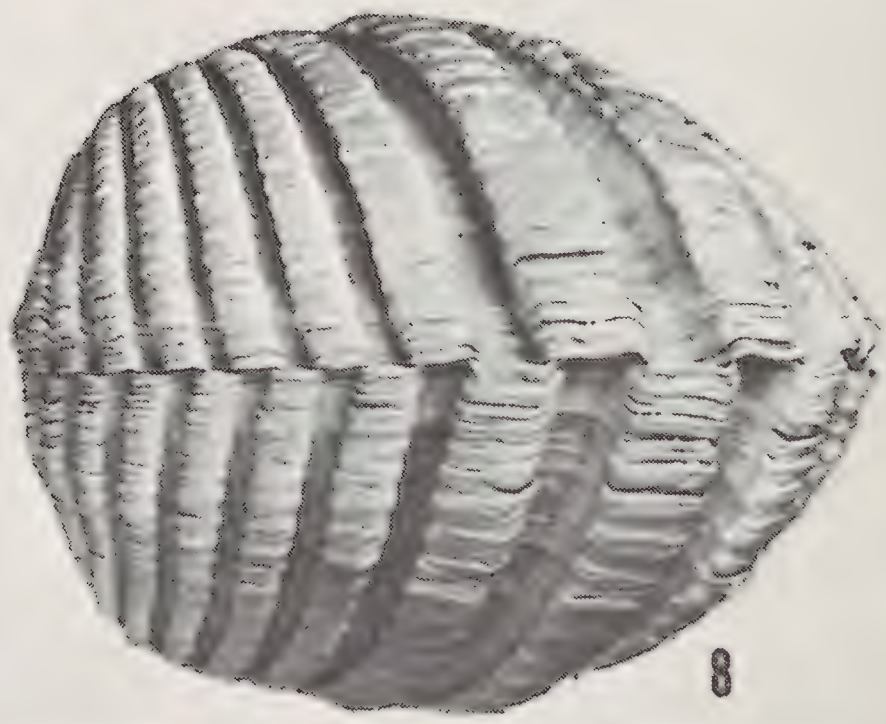




PLATE 4

? 1898 *Scapharca* (*Anadara*) *rustica* Tuomey and Holmes, DALL, Trans. Wagner Free Inst. Sci., vol. 3, pt. 4, p. 653 (part), pl. 31, figs. 6, 9.

1932 *Arca aequalitas* TUCKER AND WILSON, Bull. Amer. Paleontology, vol. 18, p. 41, pl. 5, fig. 2; pl. 6, fig. 6; pl. 7, fig. 7; pl. 9, fig. 1 (described Port Mayaca, Florida, listed as also at Prairie Creek and LaBelle, Florida).

1939 *Arca aequalitas* Tucker and Wilson, MANSFIELD, Florida Dept. Conserv., Geol. Bull. 18, p. 25 (listed, 1 mi. N. of Bermont, Charlotte Co.), 32 (listed, Bermont and St. Lucie Canal). (NOT p. 12, "dredged from Caloosahatchee River one mile below Olga" [= new species?]).

1953 *Anadara* (*Anadara*) *aequalitas* (Tucker and Wilson), OLSSON AND HARBISON, Acad. Nat. Sci. Phila., Mon. 8, p. 38 (NOT pl. 3, figs. 2, 2a).

1958 *Anadara* (*Anadara*) *rustica* (Tuomey and Holmes), DUBAR, Florida Geol. Surv. Bull. 40, p. 156 (part), pl. 1, fig. 3 (NOT figs. 2, 9).

1964 *Anadara* (*Caloosarca*) *aequalitas* (Tucker and Wilson), OLSSON AND PETIT, Bull. Amer. Paleontology, vol. 47, p. 521 (listed, "Unit A").

"*Arca*" *aequalitas* was described by Tucker and Wilson in terms of a comparison with "typical *A. rustica* Tuomey and Holmes from the Waccamaw of South Carolina." Their reference to the marked increase in the width of the posterior ribs makes it clear, however, that the actual comparison was with Florida specimens that are to be identified as *A. crassicosta.* Their description follows:

"Shell somewhat thicker than typical *A. rustica* Tuomey and Holmes from the Waccamaw of South Carolina. Beaks only slightly elevated, sulcus absent. Auriculation well developed in young specimens. Usually only sixteen ribs. Interspaces deeply excavated, usually same width as interspaces [= ribs]. None of the posterior ribs increase as markedly in width as do those in *A. rustica.* Height 51; width 39 mm."

*Anadara* (*Caloosarca*) *aequalitas* appears to be a late Pliocene or early Pleistocene descendant of *A. crassicosta,* having essentially the same number of radial ribs, but differing in their relative strength and spacing. The ribs on the anterior portion of the valve are more widely separated from each other in the present species and those on the posterior portion of the median surface are not markedly greater in width than those on the anterior part. In this latter characteristic the present species resembles *A. rustica,* from which it may be distinguished by the lesser number of radial ribs and, as earlier noted (p. 21) by the nature of the ribs on the posterior end of the valve.

A count of the number of ribs on 200 valves, 100 right and 100 left, reveals the following distribution:

| No. of ribs: | 16 | 17 | 18 | 19 | 20 | 21 | 22 | |
|---|---|---|---|---|---|---|---|---|
| No. of specimens: | | | | | | | | |
| Right valves | 5 | 14 | 27 | 23 | 20 | 8 | 3 | = 100 |
| Left valves | 7 | 18 | 27 | 20 | 13 | 12 | 3 | = 100 |
| Total | 12 | 32 | 54 | 43 | 33 | 20 | 6 | = 200 |

The statement of the original description, "Usually only sixteen ribs" suggests that the three or four relatively fine ribs of the posterior slope were not included in the counts. All are included in the figures given above.

The cardinal area and the details of the hinge structure are similar to those observed in *A. crassicosta.* The greatest varia-

PLATE 5 →

Figures Page

*Anadara* (*Caloosarca*) *aequalitas* (Tucker and Wilson) ---------- 24

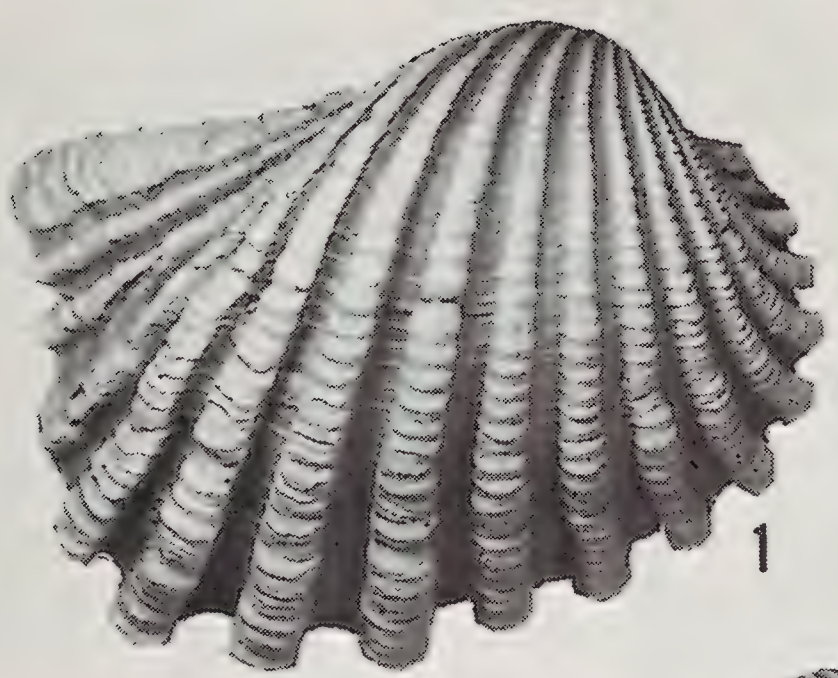
1, 2, 4, 7, 8. USNM 645927, paired valves, length 56.4 mm, height 45.1 mm, diameter 43 mm. Locality TU 580. 1. Exterior, right valve; 2. Exterior, left valve; 4. Dorsal view, conjoined valves; 7. Hinge and interior of left valve; 8. Ventral view of conjoined valves of adult individual with but 17 ribs on each valve.

3. USNM 645930, left valve, length 44 mm, height 27.7 mm. Locality TU 201. Note the strong auriculation resulting from the unusually elongated dorsal margin, a characteristic of the immature specimens of this species (see also fig. 6).

5. USNM 645928, right valve, length 46.5 mm, height 39.1 mm. Locality TU 580. Although not much more elongate than the specimen shown in fig. 3, this individual has attained adult proportions.

6. USNM 645929, right valve, length 36.5 mm, height 22.8 mm. Locality TU 580.

All specimens from "Unit A," unnamed post-Caloosahatchee formation, late Pliocene or early Pleistocene in age, Florida. All figures approximately natural size.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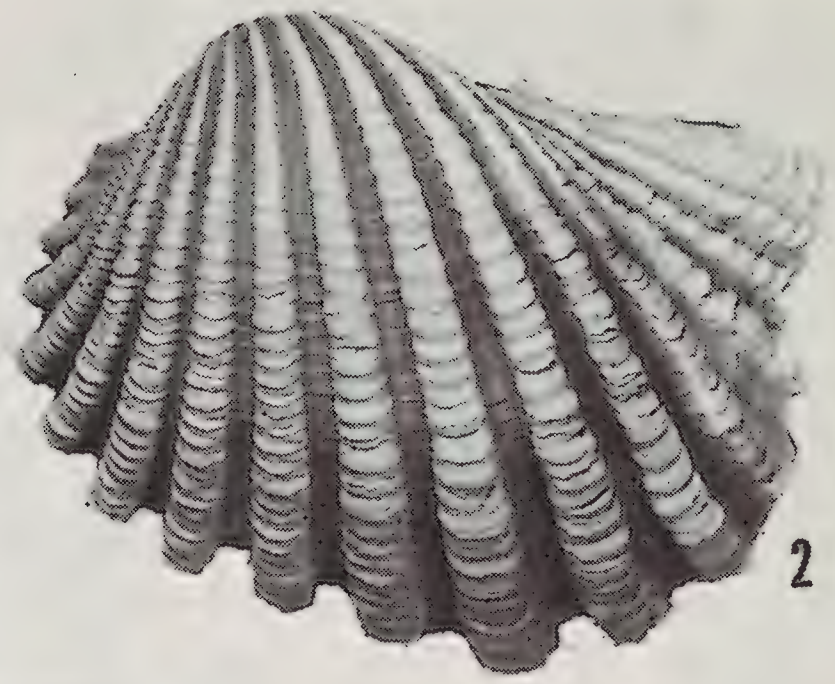
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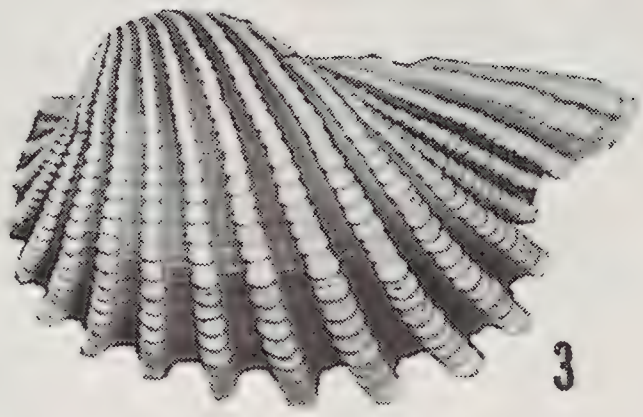
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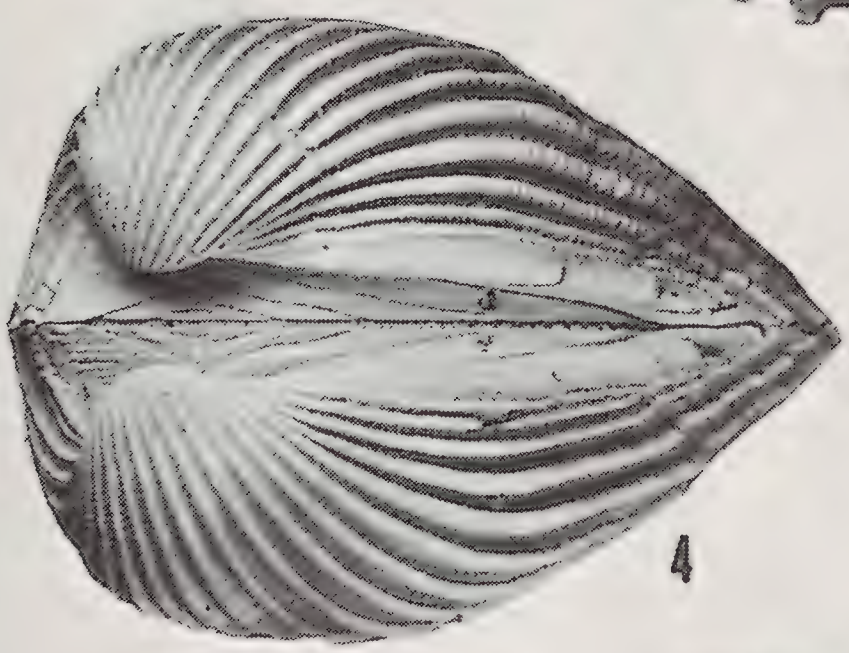
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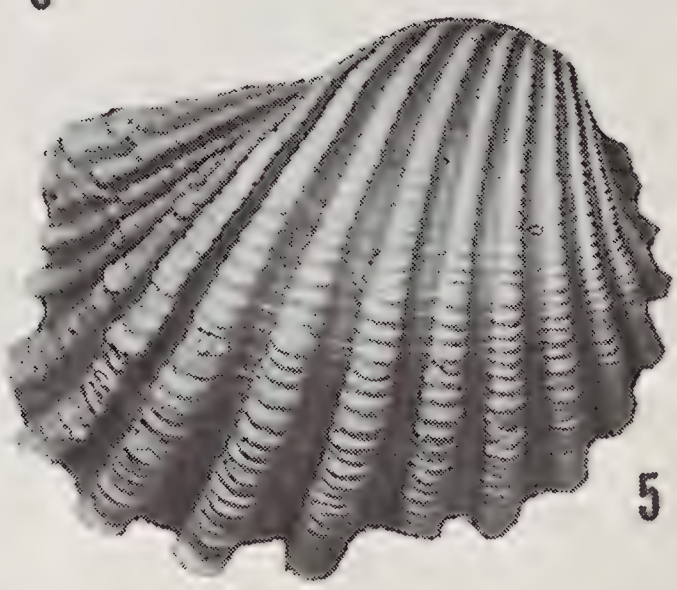
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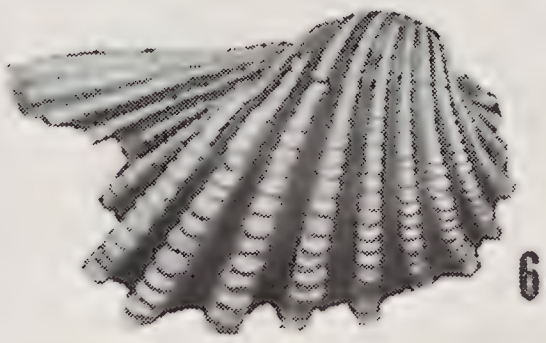
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PLATE 5

tion in tooth structure occurs in the short anterior series, although occasionally weakly chevron-shaped teeth may be observed in the latter third of the length of the posterior series.

The specimen figured by Olsson and Harbison (1953, pl. 3, figs. 2, 2a) from Clewiston, Florida, one of only two in their collections has the straighter ventral margin and narrower, more regular, beaded ribbing that marks *A. catasarca* (Dall); it does not represent the present species. However, their identification of this specimen as *A. aequalitas* led them to suggest (p. 38) that this species has a more rectangular form than does *A. rustica* [=*crassicosta*]. In the majority of the specimens in our collections the general convexity of the ventral margins of the valves of the latter two species is about the same. However, the general tendency, so marked in *A. crassicosta,* for the ventral margin to "slope" toward the posterior with the greatest width of the valve interior being located in the region dorsal to that portion of the ventral margin of the shell marked by the termination of the strong posterior umbonal ribbing, is not as pronounced in *A. aequalitas,* the result being that the interior of the valve appears to be relatively more elongately quadrangular than that of the typical *A. crassicosta.*

*Distribution*: *Anadara aequalitas* appears to have preferred an environment with a fine chalky shell-marl type of bottom. Many of the specimens are encrusted with bryozoan, coral or calcareous algal materials, serpulid worm tubes commonly occur and holes made by boring molluscs and worms are frequently present. All would attest to an environment of slow deposition.

Figured Specimen, USNM 645927: length 56.4 mm; height 45.1 mm; diameter (paired valves) 43.0 mm. Locality TU 580.

Figured Specimen, USNM 645928: length 46.5 mm; height 39.1 mm; diameter (right valve) 19.0 mm. Locality TU 580.

Figured Specimen, USNM 645930: length 44.0 mm; height 27.7 mm; diameter (left valve) 13.2 mm. Locality TU 201.

Figured Specimen, USNM 645929: length 36.5 mm; height 22.8 mm; diameter (right valve) 10.7 mm. Locality TU 580.

*Collections studied*: Tulane University localities 79, 201, 283b, 529, 580, 583, 725, 727, 732, 733, 746, 747, 748, 749, 751, 759, 978; USGS, 11152, 13835, 21982, 21984, 22038, 22039, 22853 and 22855.

## Anadara (Caloosarca) catasarca (Dall)

Plate 6, Figures 1-10; Text Figure 1b

1898 *Scapharca* (*Anadara*) *catasarca* Dall, Trans. Wagner Free Inst. Sci., vol. 3, pt. 4, p. 654, pl. 32, fig. 20 (described, Alligator Creek, Florida).

1916 *Arca catasarca* Dall, Sheldon, Palaeontogr. Americana, vol. 1, no. 1, p. 56, pl. 13, fig. 6 (orig. descr. and fig. reprinted).

1939 *Arca catasarca* Dall, Mansfield, Florida Geol. Surv. Bull. 18, p. 23 (Alligator Creek), 32 (Table of occurrences adding west side Lake Okeechobee, Coffee Mill Hammock, Caloosahatchee R. at Ortona Locks) [NOT p. 12, Caloosahatchee River 1 mile below Olga = *notoflorida* n. sp.].

1953 *Anadara* (*Anadara*) *aequalitas* (Tucker and Wilson), Olsson and Harbison, Acad. Nat. Sci. Phila., Mon. 8, pl. 3, figs. 2, 2a (Clewiston, Florida).

1958 *Anadara* (*Anadara*) *rustica* (Tuomey and Holmes) Dubar, Florida Geol. Surv. Bull. 40, p. 156 (part), pl. 1, fig. 2 (NOT figs. 3, 9).

1962 *Anadara catasarca* (Dall), Dubar, Florida Geol. Surv. Bull. 43, p. 60 (checklist, Charlotte Harbor area, Florida).

1968 *Anadara aequalitas* Tucker and Wilson, Olsson, Miami Geol. Soc. Guidebook, 2nd. Ann. Field Trip, pl. 2, fig. 7 (index fossil for Unit A).

Dall's "*Scapharca*" *catasarca* has been rather generally overlooked by students of the Tertiary faunas of Florida since its original description. Much of this stems from the fact that the original illustration represented only the hinge and interior of the holotype valve, there being no figure showing the exterior with its distinctive ornamentation.

The original description was as follows:

"Shell elongate, solid subrhomboidal, with very anterior, high prosocoelus beaks; right valve with twenty-three strong, narrow, rounded ribs, separated by wider, very deeply channelled interspaces; concentric sculpture of incremental lines, which are slightly elevated at regular intervals, and cause over much of the valve the tops of the ribs to appear obscurely nodulous; the ribs on the anterior end, though simple in the young, are sharply mesially sulcate in the adult, those on the posterior dorsal slope lower and more rude than those on the body of the shell; the hinge-line is straight, the cardinal area differs from that of *A. rustica* [= *crassicosta*] only by having but a single transverse groove anteriorly between the beaks; both valves are

similarly sculptured, but no adult left valve was collected; the hinge-line is straight and shorter than the shell; there are about fifteen anterior and four times as many similar posterior vertical teeth, the proximal ends of the series slightly overlapping; the hinge-line in the specimen figured is forty-six millimeters long, the vertical of the beak falls at 8.5 millimeters from the anterior end; inner margins thickened, with short flutings. Long. 55, alt. 36, diam. 45 mm.

"This fine species appears to be rare, and was found only at Alligator Creek, where two adult right valves, one young pair, and some fragments were obtained. The young has much the outline of *A. auriculata* [= *notabilis*], but is not markedly auriculate. It is proportionately shorter than the adult. The species belongs in the same subordinate group as *A. rustica* [= *crassicosta*], as shown by the minor characters."

This species appears to be rare in the "Unit A" (late Pliocene or early Pleistocene) deposits exposed in the more western portions of the Florida peninsula. Dall's original hypodigm included the few specimens from Alligator Creek and a single broken valve, "probably of this species," from Shell Creek. Apparently later collecting has added to the USNM collections 2 small valves from the Alligator Creek and 2 from the Shell Creek localities. In addition, there are 3 valves collected by Mansfield and MacNeil from Acline, Charlotte Co. It is not present in the Tulane University collections from either of these localities. We have four valves, two right and two left, from the Cecil M. Webb Wildlife Management Area in Charlotte County, south of Punta Gordo, Florida (TU-816). In contrast, the species is abundant in material recently dredged in the widening and deepening of the Caloosahatchee Canal at, and up to about five and one-half miles eastward from the Ortona Locks. Our collections from this area contain more than 200 valves. It also is moderately abundant at a number of localities in Palm Beach County, southeastward from Lake Okeechobee.

A count of the ribbing on 200 specimens, 100 right and 100 left valves, reveals the following distribution:

| No. of ribs: | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | |
|---|---|---|---|---|---|---|---|---|---|---|
| No. of specimens: | | | | | | | | | | |
| Right valves | 2 | 10 | 18 | 22 | 15 | 21 | 9 | 1 | 2 | = 100 |
| Left valves | 0 | 4 | 19 | 23 | 23 | 17 | 11 | 2 | 1 | = 100 |
| Total | 2 | 14 | 37 | 45 | 38 | 38 | 20 | 3 | 3 | = 200 |

The mesial sulcation of the anterior ribs, remarked by Dall as a characteristic feature of the species, proves on examination of a series of specimens to be a variable feature and not reliable for specific identification. As may be noted in the illustration of Plate 6, Fig. 9, the anterior ribs are simple and more or less rounded on top in the earlier stages of development, the mesial sulcation when present appearing only in the more adult stage. Many specimens, probably a majority of those in the collections, do not show a sulcation, the adult ribs tending instead to assume a relatively subtriangular section with a relatively ridged, non-sulcate top. Sulcations, when present are most strongly impressed into the third, fourth, and fifth ribs from the dorsal margin; the first and second ribs are seldom, if ever, modified in any way.

The features of the hinge and cardinal area are typical of the subgenus. A majority of the specimens show at least three posterior ligamental grooves prior to their appearance on the anterior area. The hinge, as in *A. crassicosta* and *A. aequalitas,* shows the greatest tendency for the modification of the teeth in the area of the short anterior series. The development of a weak chevron-shape in the teeth of the median part of the longer posterior series is almost always to be observed, with the apex of the chevron pointing anteriorly. Those teeth anterior and posterior to the chevrons are directly transverse.

Muscle scars and interior of the valve show no features unique to the species.

*Anadara catasarca* appears to be descended from *A. aequalitas* and some specimens are assignable with difficulty to one species or the other. The typical forms, however, may be rather readily distinguished by the more triangular shape of the ribs in *A. catasarca* and the resultant appearance of greater width of the interspaces. The steep-sided ribs of *A. aequalitas* often show a tendency to be grooved just below their crests making the crests the widest part of the rib, rather than the narrowest as in *catasarca.* Furthermore the ribs on the main portion of the valve are all of approximately equal strength with no tendency toward greater width posteriorly.

Holotype, USNM 107713: length 56.7 mm; height 36 mm; diameter (right valve) 22 mm. Alligator Creek, Charlotte Co., Florida.

Figured specimen, USNM 645931: length

56.1 mm; height 39 mm; diameter (both valves) 41.4 mm. Locality TU 759.
Figured specimen, USNM 645934: length 56.3 mm; height 38.7 mm; diameter (right valve) 22.5 mm. Locality TU 803.
Figured specimen, USNM 645932: length 37.4 mm; height 28 mm; diameter (left valve) 13.4 mm. Locality TU 759.
Figured specimen, USNM 645935: length 32 mm; height 24.9 mm; diameter (right valve) 12.8 mm. Locality TU 803.
Figured specimen, USNM 645933: length 20 mm; height 13.8 mm; diameter (right valve) 6.5 mm. Locality TU 759.
Figured specimen, USNM 645939: length 74 mm; height 52.5 mm; diameter (right valve) 26.5 mm. Locality TU 201.

*Collections studied*: Tulane University localities 79, 201, 579, 580, 725, 727, 731, 746, 749, 759, 767, 768, 802, 803, 816, 939; USGS 22038, 22444, 22855, 13975, 22742, 23089, 22853.

## Anadara (Caloosarca) notabilis (Röding)

Plate 1, Figures 8-12, Text Figure 1a

1783 Varietas notabilis praecedentis speciei [*Arca scapha* = *antiquata*], Chemnitz, Neues Systematisches Conchylien-Cabinet, vol. 7, p. 166, 205, pl. 55, fig. 549.
1798 *Arca Notabilis* Röding, Mus. Boltenianum, p. 173.
1843 *Arca Deshayesii* Hanley, An Illustrative and Descriptive Catalogue of Recent Bivalve Shells, p. 157 (fft.).
1843 *Arca Deshayesii* Reeve, Philippi, Abbild. u. Beschr. Conch., vol. 1, p. 30, *Arca,* pl. 2, fig. 3.
1844 *Arca Deshayesii* Hanley, Reeve, Conch. Icon., vol. 2, *Arca,* pl. 7, sp. 47.
1845 *Arca auriculata* (Lamarck), D'Orbigny, *in* de la Sagra, Historia fisica, politica y natural de la Isla de Cuba, vol. 5, Moll., p. 345 [p. 321 in French ed., *fide* Dall, 1885, p. 25] (NOT *A. auriculata* Lamarck, 1819, p. 43, Red Sea species).
1853 *Anadara natabilis* [sic] Bolten [=] *A. Deshayesii* Hanl. Reeve, Moerch, Cat. Conch. Comes de Yoldi, fasc. 2, p. 41 ("Antill.").
1858 *Arca Deshayesii* Hanley, Beau, Cat. cog. rec. a la Guadaloupe . . . , p. 22.
1864 "*Arca notabilis* Bolt. (*Anodara* Gray. *A. Deshayesii* Hanley)" Krebs, The West Indian Marine Shells, p. 125 ("Habitat: Antillae, . . . Guadalupe . . . Virgin-Islands.")
1878 *Arca notabilis* Bolten = *A. Deshayesii* Hanley, Moerch, Cat. West India shells . . . coll. . . . Poulsen, p. 16 (*fide* Dall, 1885, p. 28).
1879 *Arca auriculata* Lamarck, Arango y Molina, Contr., fauna malac. Cubana, p. 262.
1881 *Arca* (*Andara*) *deshaysii* [sic] Hanley, Gabb, Acad. Nat. Sci., Phila., Jour., ser. 2, vol. 8, p. 378 ("Pliocene," Costa Rica).
1886 *Arca auriculata* Lamarck, Dall, Harvard Mus. Comp. Zoology, Bull., vol. 12, no. 6, p. 191, 241 (27 fthms., Flannegan's Passage [Virgin Isls.]; 35 fthms., off Havana).
NOT 1889 *Arca* aff. *Deshayesii* Hanley, Lorie, Samml. Geol. Reichs.-Mus. Leiden, ser. 2, vol. 1, p. 116-118, 141, pl. 1, fig. 9 (Pleistocene, Curacao) [prob. = *hemidesmos* (Philippi)].

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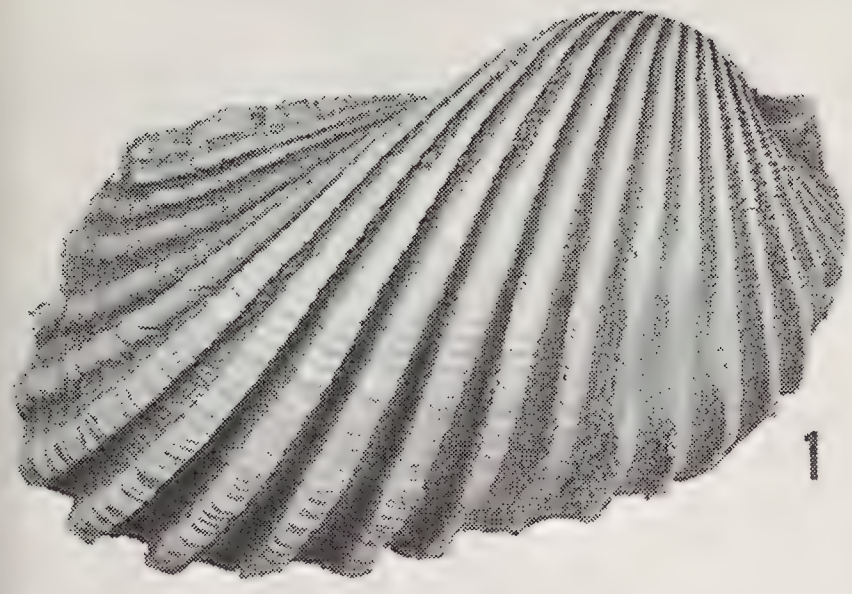
## Plate 6

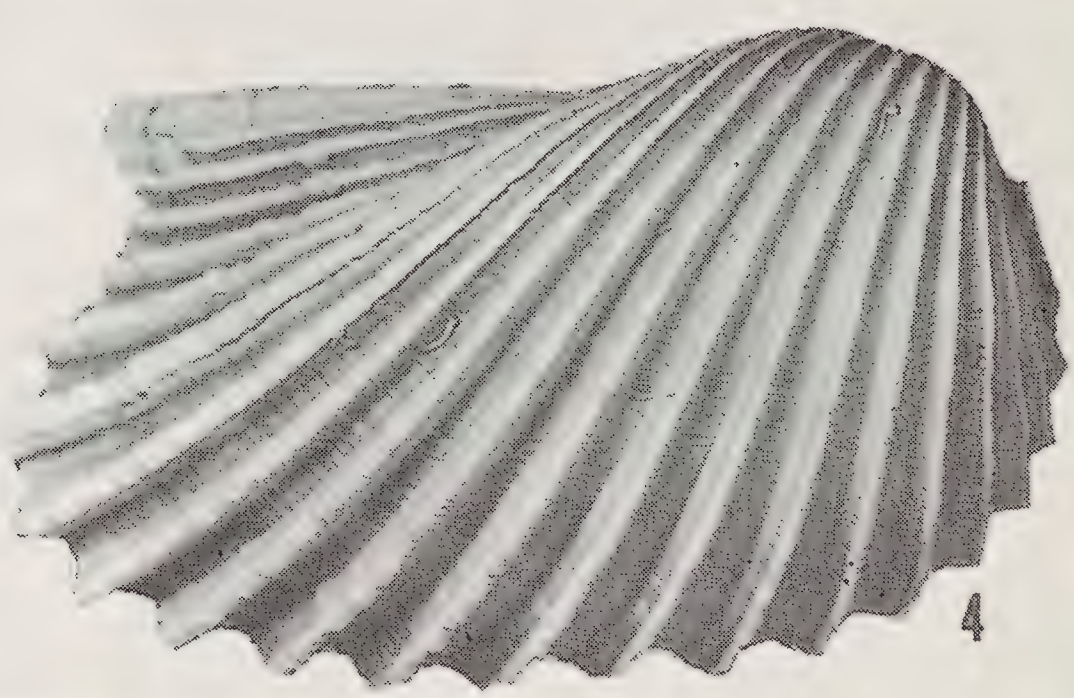
Figures

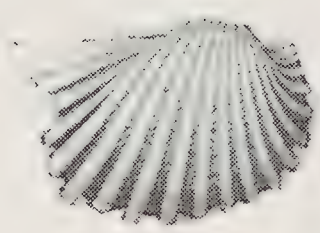
*Anadara* (*Caloosarca*) *catasarca* (Dall) ---------- 28

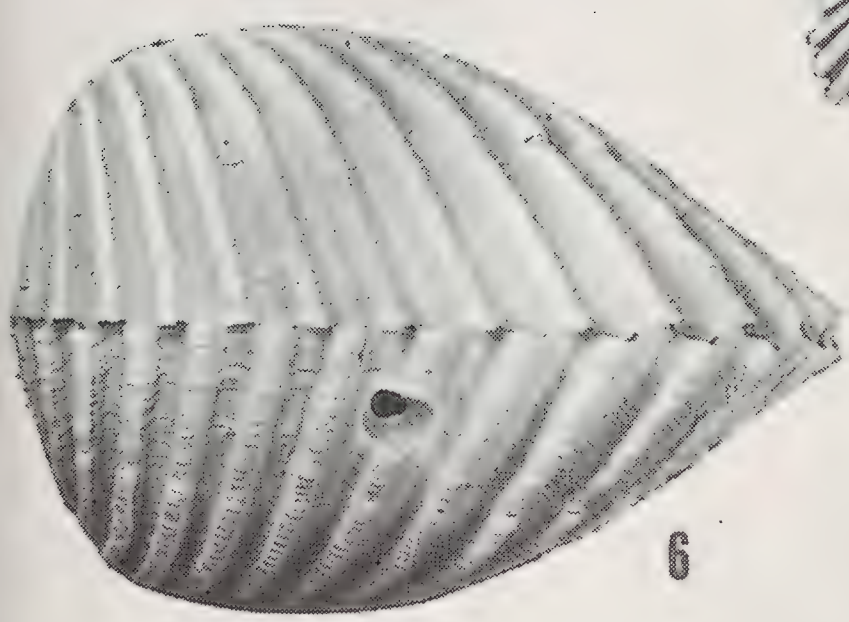
1. USNM 107713 (holotype), right valve, length 56.7 mm, height 36 mm. Locality, Alligator Creek, Charlotte Co., Florida.
2, 6, 7, 9. USNM 645931, length 56.1 mm, height 39 mm, diameter (paired valves) 41.4 mm. Locality, TU 759. 2. Left valve; 6. Ventral view of conjoined valves; 7. Hinge and interior of left valve; 9. Anterior view of conjoined valves, note median grooving of some of the ribs.
3. USNM 645934, right valve, length 56.3 mm, height 38.7 mm. Specimen with relatively narrow, straight-sided ribs. Locality, TU 803.
4. USNM 645939, right valve, length 74 mm, height 52.5 mm. Largest specimen in Tulane University collections, note the subtriangular, crested ribs. Locality TU 201.
5. USNM 645933, right valve, length 20 mm, height 13.8 mm. Note the strongly auriculate outline and rounded ventral margin of immature specimens. Locality TU 759.
8. USNM 645932, left valve, length 37.4 mm, height 28 mm. Locality TU 759.
10. USNM 645935, right valve, length 32 mm, height 24.9 mm. Locality TU 759.

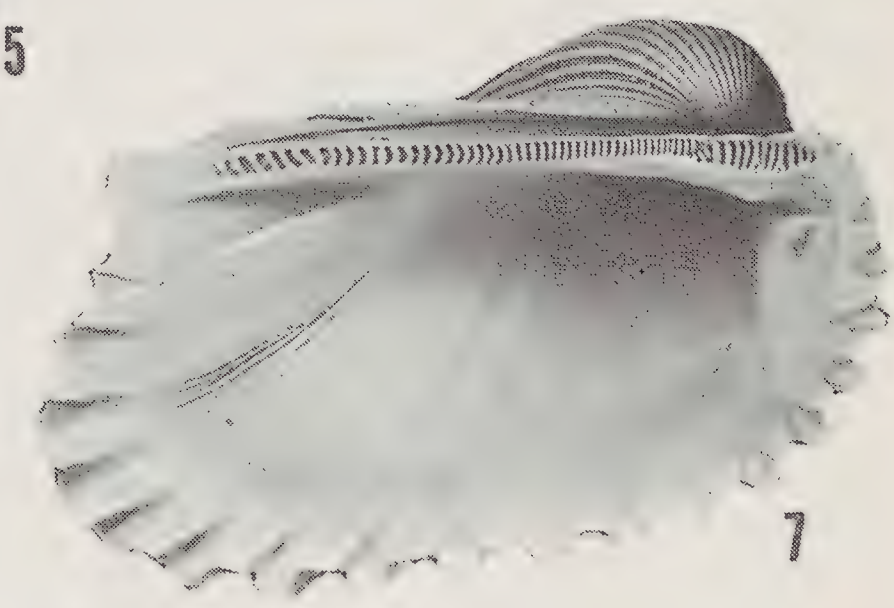
All specimens from "Unit A," unnamed post-Caloosahatchee formation, late Pliocene or early Pleistocene in age, Florida. All figures approximately natural size.

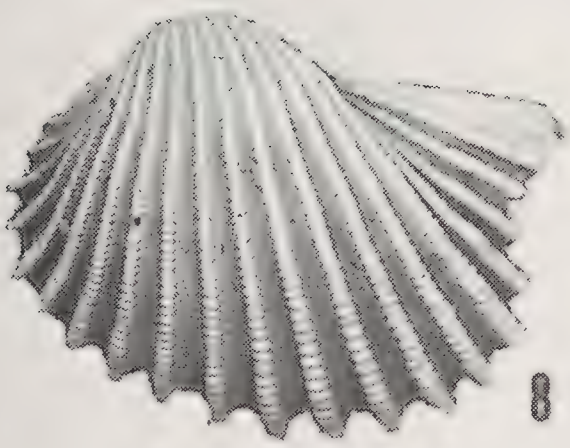


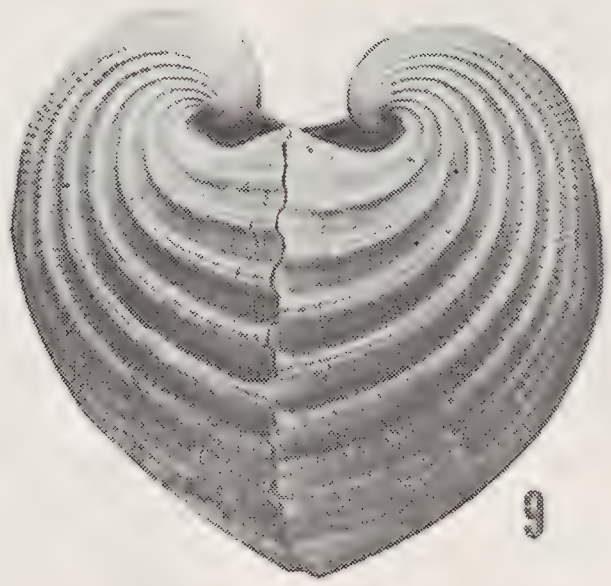


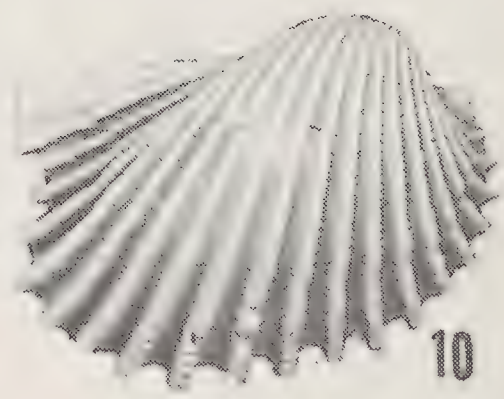




PLATE 6

1889 *Arca* (*Scapharca*) *auriculata* Lamarck, DALL, U. S. Natl. Mus. Bull. 37, p. 40 (15 to 40 fathms., Texas, Key West to Martinique).

1891 *Arca Deshayesii* Hanley, BAKER, Acad. Nat. Sci. Phila., Proc., vol. 43, p. 47 (Recent, north coast Yucatan).

1896 *Arca Deshayesii* [Hanley], HEILPRIN, *in* SAPPER, Bol. Inst. Geol. de Mexico, no. 3; partial translation by Maury and Harris, Jour. Geology, vol. 4, no. 8, p. 938-947, see p. 945. ("Pliocene," Merida, Yucatan).

1897 *Arca* (*Anomalocardia*) *auriculata* Lamarck, VON IHERING, Rev. Mus. Paulista, vol. 2, p. 82. (Brazil).

1898 *Scapharca* (*Scapharca*) *auriculata* Lamarck, DALL, Trans. Wagner Free Inst. Sci., vol. 3, pt. 4, p. 649 (part), 659. (Pliocene, Costa Rica; Pleistocene, Antilles; Recent, Key West to Martinique, in 15 to 40 fathms.) [NOT Bowden, Jamaica (= *"Barbatia* (*Diluvarca*)*" prephina* Woodring)].

1898 *Scapharca Deshayesii* Hanley, DALL, Trans. Wagner Free Inst. Sci., vol. 3, pt. 4, p. 659 (Pliocene of Costa Rica; Recent, southern coasts of U. S.).

1901 *Arca deshayesii* Hanley, DALL, Wash. Acad. Sci., Proc., vol. 3, p. 141 (Recent, Pernambuco, Brazil).

1901 *Arca deshayesii* Hanley, DALL AND SIMPSON, U. S. Fish Comm., Bull., vol. 20, pt. 1, p. 461, 510 (Recent, Mayaguez & San Juan, Porto Rico; Vieques Isl.).

1907 *Arca deshayesii* Hanley, LAMY, Jour. Conchyl., vol. 55, p. 218-221. (Recent, in coll. Mus. d'Hist. Nat., Paris).

1913 *Arca deshayesii* Hanley, BROWN AND PILSBRY, Acad. Nat. Sci. Phila., Proc., vol. 65, p. 496 (Pleistocene, Canal Zone).

1913 *Arca* (*Cunearca*) *deshayesii* Hanley, JENKINS, Amer. Philos. Soc., Proc., vol. 52, no. 211, p. 457 (Quaternary, Rio Grande do Norte, Brazil).

1916 *Arca Deshayesii* Hanley, SHELDON, Palaeontogr. Americana, vol. 1, no. 1, p. 50, pl. 11, figs. 15-18 (Recent, West Indies; fossil, mainland of southern North America; fig'd. from Guadalupe and Jamaica).

1916 *Arca auriculata* Lamarck, SHELDON, Palaeontogr. Americana, vol. 1, no. 1, p. 50, pl. 11, fig. 19 (fig'd., Recent, Florida).

1917 *Scapharca auriculata* Lamarck, MAURY, Bull. Amer. Paleontology, vol. 5, p. 339, pl. 54, fig. 3; p. 445. (Santo Domingo—see discussion below).

1919 *Arca deshayesii* Hanley, VAUGHAN, U. S. Natl. Mus. Bull. 103, p. 564 (common in Pleistocene near Mt. Hope, Panama Canal Zone).

1920 *Scapharca* (*Scapharca*) *auriculata* Lamarck, MAURY, Bull. Amer. Paleontology, vol. 8, p. 50 (repeats Dall, 1889, distribution information).

1922 *Arca deshayesii* Hanley, REMINGTON, Nautilus, vol. 35, no. 4, p. 121.

1922 *Arca auriculata* Lamarck, OLSSON, Bull. Amer. Paleontology, vol. 9, p. 362, pl. 25, fig. 3 ("Gatun Stage," Costa Rica [see below]).

1925 *Scapharca* (*Scapharca*) *auriculata* Lamarck, MAURY, Bull. Amer. Paleontology, vol. 10, p. 201, pl. 15, fig. 2 (Recent, Erin Point, Trinidad; "We have gathered recent specimens on the Texas coast and on the beach at Monte Cristi, Dominican Republic.")

1925 *Scapharca* (*Scapharca*) *dehayesi* [sic] Hanley, MAURY, Bull. Amer. Paleontology, vol. 10, p. 201, pl. 15, fig. 3 [as *deshayesii* in pl. desc.] (Recent, Guadalupe; Quaternary, Curacao).

1926 *Arca* (*Scapharca*) *auriculata* Lamarck, WEISBORD, Nautilus, vol. 39, no. 3, p. 82 (Recent, Progreso and Sabancuy, Yucatan).

?, 1927 *Arca* (*Scapharca*) *auriculata* Lam., ANDERSON, California Acad. Sci., Proc., ser. 4, vol. 16, no. 3, p. 89 (listed, Stage "M," lower Miocene, Tubera Mountain, near Puerto Colombia, Colombia).

?, 1929 *Arca* (*Scapharca*) *auriculata* Lamarck, ANDERSON, California Acad. Sci., Proc., ser. 4, vol. 18, no. 4, p. 149-150 (Miocene, northern Colombia).

NOT 1933 *Scapharca* cf. *Deshayesii* Hanley, TRECHMANN, Geol. Mag., vol. 70, no. 823, p. 34, pl. 4, fig. 1 (Pleistocene, Barbados) [= *hemidesmos* (Philippi)].

1934 *Arca auriculata* Lamarck, 1819 (*A. deshayesii* Hanley 1843), JOHNSON, Boston Soc. Nat. Hist., Proc., vol. 40, no. 1, p. 19 (Recent, Florida Keys and West Indies).

1935 *Arca auriculata* Lamarck, RICHARDS, Jour. Paleontology, vol. 9, p. 256 (Pleistocene, western Cuba).

1936 *Arca auriculata* Lamarck, MCLEAN, Soc. Cubana Hist. Nat. "Felipe Poey," Mem., vol. 10, no. 1, p. 39 (Recent, Santa Clara Prov., northern Cuba).

1936 *Arca auriculata* Lamarck, CLENCH AND MCLEAN, Soc. Cubana Hist. Nat. "Felipe Poey," Mem., vol. 10, no. 3, p. 159 (Recent, Cat, Little Salvador and New Providence Islands, Bahamas).

1936 *Arca auriculata* Lamarck, MCLEAN, Nautilus, vol. 49, no. 4, p. 116 (Recent, Bahama Is.).

1936 *Arca auriculata* Lamarck, RICHARDS, Nautilus, vol. 39, no. 4, p. 133-4 (North Carolina "Banks").

1937 *Arca auriculata* Lamarck, SMITH, East Coast Marine Shells, p. 26, pl. 3, figs. 8a, b.

1938 *Arca auriculata* Lamarck, PERRY, SCHWENGEL AND DRANGA, Nautilus, vol. 52, no. 1, p. 27 (dredged, Sanibel Isl., Florida).

1938 *Arca auriculata* Lamarck, RICHARDS, Geol. Soc. America, Bull., vol. 49, p. 1290 (Pleistocene, near Fort Lauderdale, Florida).

1940 *Arca auriculata* Lamarck, PERRY, Bull. Amer. Paleontology, vol. 46, no. 95, p. 29, pl. 1, figs. 6a, b (dredged in 3 to 6 fathoms, southwest Florida).

1942 *Anadara auriculata* Lamarck, JAUME AND PÉREZ FARFANTE, Soc. Cubana Hist. Nat. "Felipe Poey," Mem., vol. 16, no. 1, p. 38 (Pleistocene, Mariel, Matanzas and Guantanamo, Cuba).

1945 *Arca auriculata* Lamarck, VAN BENTHEM JUTTING, Geolog.-Mijnbouwk. Genootschap

Nederland en Kolonien, Geol. ser., vol. 14, p. 77 (Quaternary, northern South America).

1946 *Arca* (*Scapharca*) *auriculata* Lamarck, Jaume, Soc. Malac. "Carlos de La Torre," Rev., vol. 4, no. 3, p. 98. (Recent, Progreso and Sabancuy, Yucatan).

1949 *Arca* (*Arca*) *auriculata* Lamarck, Lange de Morretes, Arq. Mus. Paranaense, vol. 7, art. 1, p. 9 (Brazil).

1951 *Arca* (*Scapharca*) *auriculata* Lamarck, McLean, Sci. Surv. Porto Rico and Virgin Islands (N. Y. Acad. Sci.), vol. 17, pt. 1, p. 16, pl. 2, fig. 9.

?, 1953 *Arca* (*Arca*) *deshayesii* Hanley, Haas, Fieldiana—Zoology, vol. 34, no. 20, p. 203 (listed, Ilha Grande, Rio de Janeiro, Brazil).

1953 *Arca* (*Scapharca*) *auriculata* Lamarck, Haas, Fieldiana—Zoology, vol. 34, no. 20, p. 203 (listed Ilha Grande, Rio de Janeiro, Brazil).

1954 *Anadara* (*Larkinia*) *notabilis* (Röding), Abbott, American Seashells, p. 344, pl. 37, fig. p. ("Rare in Florida; common in the West Indies").

1955 *Anadara* (*Scapharca*) *notabilis* (Röding) (*A. auriculata* Lam.), Perry and Schwengel, Marine Shells of the Western Coast of Florida, p. 35, pl. 1, figs. 6a, b (reprints descr. and figs. of Perry, 1940).

1955 *Anadara notabilis* Röding, Hulings, Invest. benthic mar. invert. fauna from shallow waters off Texas coast (unpubl. M. A. thesis, Texas Christian Univ.), p. 21 (sta. 25, sandy shell debris, 40 feet, dead), 23 (sta. 27, Sabine Bank, shell debris, 42 feet, dead), 31 (sta. 46, sandy mud at 42 feet, live), 54 (not previously recorded from Texas coast), 70.

1958 *Anadara notabilis* (Röding), Olsson and McGinty, Bull. Amer. Paleontology, vol. 39, no. 177, p. 19 (Bocas Isl., northwest coast of Panama).

1958 *Anadara* (*Larkinia*) *notabilis* Röding, Abbott, Acad. Nat. Sci., Phila., Mon. 11, p. 111 (alive, North Sound and Duck Pond, Grand Cayman Isl., in 5 to 15 feet water on sand and grass bottom).

1959 *Anadara notabilis* Röding, Nowell-Usticke, Check List Marine Shells of St. Croix, U. S. Virgin Islands, p. 1 ("not common—Altona Bay and Lagoon. Sugar Bay" St. Croix).

1959 *Anadara notabilis* (Röding), Newell, Imbrie, Purdy and Thurber, Amer. Mus. Nat. Hist. Bull., vol. 117, art. 4, p. 218, 222, [Great Bahama Bank, "*Strombus samba* community (outer platform, unstable sand bottom, generally deeper than 2 fathoms)" and "*Strombus costatus* community, (shelf lagoon and marginal lagoons, stable sand bottom, generally less than 1.5 fathoms)."]

1961 *Arca* (*Anadara*) *notabilis* Roeding, van Regteren Altena, Konikl. Nederl. Akad. Wetensch.-Amsterdam, Proc., ser. b, vol. 64, no. 2, p. 298 (Post-Miocene, probably Pleistocene, St. Kitts and St. Eustatius Isl.).

1961 *Anadara* (*Larkinia*) *notabilis* Röding, Warmke and Abbott, Caribbean Seashells, p. 159, pl. 30, fig. h (Florida to the Caribbean and Brazil, "very common . . . in shallow water on mud and grass").

1961 *Anadara* (*Caloosarca*) *notabilis* (Roeding), Olsson, Panama-Pacific Pelecypoda, p. 98, pl. 8, fig. 3 (referred to subgenus *Caloosarca* with fig. of hinge of specimen from Pass-a-Grille, Florida).

1961 *Anadara notabilis* (Roeding), Weber, Nautilus, vol. 75, no. 2, p. 58 (Water Is., Virgin Isls. Group).

1962 *Anadara notabilis* (Röding), Richards, Amer. Philos. Soc., Trans., vol. 52, pt. 3, p. 52, pl. 1, figs. 31, 32 (Pleistocene, Cape Hatteras, North Carolina, Recent, northern Florida to Brazil; fig'd. Recent, Snipe Key, Florida).

1962 *Anadara notabilis* (Röding), Rehder, Jour. Paleontology, vol. 36, no. 3, p. 585 (Pleistocene, Grand Cayman Isl.).

1964 *Anadara* (*Larkinia*) *notabilis* (Röding), Weisbord, Bull. Amer. Paleontology, vol. 45, p. 69-72, pl. 5, figs. 7, 8 (NOT figs. 9, 10) (extended bibliography and discussion; fig'd., Recent, Venezuela).

1965 *Anadara* (*Cara*) *auriculata* (Lamarck, 1819), Glibert and van de Poel, Inst. Roy. Sci. Nat. de Belgique, ser. 2, fasc. 77, p. 52 (Pleistocene, Port Limon, Costa Rica).

1967 *Anadara notabilis* (Röding, 1798), Hebard, Nautilus, vol. 81, no. 2, p. 41 (Pleistocene, New Providence Isl., Bahamas).

This species was originally named by Röding (1798, p. 173) without description, but with a reference to a figure in Chemnitz (1783, pl. 55, fig. 549), denominated as a "Varietas notabilis praecedentis speciei," which was said to represent *Arca scapha,* a species now referred to *A. antiquata* Linnaeus. In his discussion of the "varietas" Chemnitz noted that it had only 24 to 26 ribs in contrast to the 35 to 36 ribs present on *A. scapha.* The only locality mentioned is through a reference to Favart d'Herbigny "Dict. tom 1. pag. 250" who states that it is "trouvé dans les mers de l'Amérique."

Early authors confused this species with *Arca antiquata* Linnaeus. Judging from the locality and the inadequate description accompanying them, the very poor figures given by Sloane (1725, tab. 241, figs. 14-16) cited by Linnaeus in the original description of his *A. antiquata,* probably represent the present species, although they were interpreted by d'Orbigny (1845, p. 345) as "*Hemidermos*" Philippi [= *hemidesmos*], a much rarer species in collections. Similarly, the figure given by Lister (1692 (?), vol. 2, pl. 236, fig. 70) of a specimen from Jamaica which was cited by Linnaeus in the synonymy of *A. antiquata* in the 12th edition of the Systema, is a good representation of

the present species, while the figure in Chemnitz, cited by Röding at the time he named *A. notabilis,* is listed by Lamarck (1819, p. 42) in his synonymy of *A. antiquata* with, however, an Old World distribution.

Weisbord (1964, p. 71) describes this species in the following terms:

"Shell inflated, oblong-rhomboidal, slightly tapering anteriorly, auriculate behind. Anterior end rounded, base gently curved, posterior margin concave above. Beaks high, well forward, separated by a moderately wide lanceolate cardinal area which is scored with several long, irregular, obtusely angled ligamental grooves. Hinge line fairly straight, the hinge itself bearing numerous comb-like teeth of which there are 15 to 18 anterior and 35 to 39 posterior. The posterior teeth are smaller than the anterior at the point of divergence of the hinge and tend to over-ride the initial anterior one. The anterior teeth at the point of divergence of the hinge may be larger than the ones immediately forward but they are longest at the distal end; the posterior teeth, on the other hand, enlarge gradually and regularly toward the posterior end. The teeth do not reach the basal margin of the hinge which is thick and smooth. Inner margin broadly corrugated. Exterior sculptured by 27 or 28 straight radial ribs crossed by numerous, more or less equally spaced concentric threads which are sharp in the interspaces but form crenations on the crest of the ribs, particularly on the lower half of the disk and on the ends. The interspaces on the disk are as wide as, or in places a trifle wider, than the ribs themselves. The color of the Recent shell is whitish, and such of the periostracum that remains is brown and silky."

The above description is somewhat incomplete in failing to note that the anterior ribs tend to be medially grooved. The most dorsally situated of these ribs seems never to be so ornamented, the grooving generally, but not always, first appearing on the second rib below the cardinal margin. The number of ribs bearing these grooves is variable. A count on 25 specimens revealed a variation between 3 and 9, with an average of 5 or 6. The total number of ribs is also variable, but there is no observable correlation between the number of ribs bearing grooves and the total number of ribs on the valve. A count of ribs on 200 specimens reveals the following distribution:

| No. of ribs: | 25 | 26 | 27 | 28 | 29 | 30 | |
|---|---|---|---|---|---|---|---|
| No. of specimens: | | | | | | | |
| Right valves | 5 | 19 | 38 | 16 | 8 | 3 = | 89 |
| Left valves | 2 | 23 | 44 | 25 | 17 | 0 = | 111 |
| Totals | 7 | 42 | 82 | 41 | 25 | 3 = | 200 |

The individual ribs (see Text-fig. 1a) are lower and usually more round-topped than are those of the other species referred to *Caloosarca.* They are, however, relatively variable; in some specimens almost straight-sided and relatively flat-topped, in others the sides are sloping and the tops proportionately narrowed until they are almost triangular in profile. Even the flat-topped ones generally tend to become notably rounded in later, gerontic stages. Interspaces between the ribs are approximately as wide as the adjacent ribs.

The shape of the valve varies with age. Younger individuals tend to be more produced and auriculate posteriorly and higher in proportion to total length. Measurement of a number of smaller specimens, 15 to 20 mm in length, reveals an average height that is 85.6 percent of the length, while specimens more than 50 mm in length tend to average 72.4 percent. The specimen figured by Perry (1940, pl. 1, fig. 6b) and by Perry and Schwengel (1955, pl. 1, fig. 6b) is unusually elongate, more so than any represented in the collections presently available for this study. As measured on their illustration, the height of this specimen is but 65.7 percent of total length.

The cardinal area is typical of that shown by other species referable to *Caloosarca.* The majority of specimens show two posterior ligamental grooves before their first appearance anteriorly. There are, however, specimens in the collections that reveal as many as five posterior grooves with no trace of any anterior ones. Hinge and interior of the valve are typical in every respect.

*Distribution*: *Anadara* (*Caloosarca*) *notabilis* has been reported, under various names,* from the Miocene to the Recent

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* The genus *Larkinia* Reinhart, 1935, to which Abbott and some other recent authors have referred this species is characterized by a high, subtrigonal and non-auriculate valve, a somewhat curved hinge line on which the cen-

in the Antillean-Caribbean region. The Miocene records from Jamaica, Santo Domingo, Costa Rica and Colombia, are, however, all highly suspect and probably none represent the present species. The Bowden, Jamaica, record given by Dall (1898, p. 649) was based upon the form subsequently named by Woodring (1925, p. 44, pl. 4, fig. 8) as *Barbatia (Diluvarca) prephina.* The Dominican record is based on a single valve reported by Maury (1917, p. 339, pl. 54, fig. 3) from Sabaneta "(loose, not *in situ*)" and (p. 445) as "lying loose on top of [bed] 3 [the uppermost Tertiary bed in the section]. [Its] origin is unknown." The specimen from Costa Rica figured by Olsson (1922, p. 362, pl. 25, fig. 3) as being from the "Gatun Stage" at "Old Man Sam Creek, one mile south of the beach," agrees in all details with similar small specimens in our collections from the Moín Formation at Moín and Puerto Limon (TU locs. 953 and 954). Olsson also reported the occurrence of the species at Hone Walk Creek. Since both these Olsson localities occur high in the Costa Rican section, and since *Anadara notabilis* is unknown in the fauna of the true Gatun deposits, either in Panama or in Costa Rica, it seems probable that Olsson's specimens were of Moín age. Anderson's record (1927, p. 89; 1929, p. 149) from the Miocene of northern Colombia is based upon unfigured material and cannot be evaluated at this time.

Gabb (1881, p. 378) reported *A. notabilis* [as "*Arca* (*Andara*) *Deshaysii,* Hanley"] from "the Pliocene Clay Beds between Limon and Moen, Costa Rica." These deposits, which are now referred to the Moín Formation, contain *Arcohelia limonensis* Vaughan and *Acrosterigma declive* (Gabb), species that were considered by Olsson and Petit (1964, p. 521) as among the forms characteristic of their "Unit A" which lies unconformably upon the Caloosahatchee Formation and is thought to be of later Pliocene (Emerson, 1964, p. 8) or earliest Pleistocene age.

Similarly the limestones exposed in the immediate vicinity of Merida, Yucatan, which had been referred to the Pliocene are now known to be of Pleistocene age (Dr. A. E. Weidie, personal communication).

*Anadara notabilis* is widely distributed in the Pleistocene, ranging from Cape Hatteras, North Carolina (Richards, 1962, p. 52) to Brazil (Jenkins, 1913, p. 457) being reported from Florida and the Bahama Islands, Cuba, Grand Cayman Isl., Central America (Yucatan, Costa Rica, and Panama), Antilles (Barbados, St. Kitts and St. Eustatis, Curacao) and from northern South America. It is represented in the Recent faunas from both sides of the peninsula of Florida westward to eastern Texas and south at least as far as Ilha Grande, Rio de Janeiro, Brazil. It appears, however, not to occur in the more western parts of the Gulf of Mexico between eastern Texas and the Yucatan Peninsula. It is abundant in the Tulane collections from the northern shores of Yucatan as well as in those made from the northwestern extremities of the peninsula as far south as Isla Arenas, about 16 miles south of Celestun, but is absent in our collections southward from this point, and westward along the Campeche, Tabasco and Vera Cruz coasts. However, the much more extensive collections of Dr. E. Wyllys Andrews of Merida, Yucatan, contain one or two isolated valves from Chenkan and Isla Aguada, on the southwestern Campeche coast.

Figured Specimen USNM 694047: Length 52.5 mm; height 39 mm; diameter (left valve) 18.6 mm. Locality TU R-109.

Figured Specimen USNM 694048: Length 47.8 mm; height 35.8 mm; diameter (right valve) 17.0 mm. Locality TU R-109.

Figured Specimen USNM 694049: Length 33 mm; height 26.1 mm; diameter (paired valves) 21.5 mm. Locality TU R-109.

*Collections studied*: Tulane University localities 953, 954, R-9, R-18, R-35, R-36, R-69, R-71, R-74, R-76, R-78, R-79, R-82 R-100, R-105, R-109, R-110, R-115, R-124, R-127, R-128, R-130, R-132, R-164, R-171, R-172.

## VII. Paleoecological Observations

As may be noted from the annotations to the synonymy of *Anadara (Caloosarca) notabilis,* that species has been reported

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tral teeth are vertical and the lateral teeth divergent, and, more importantly, a triangular cardinal area on which the ligament covered the anterior as well as the posterior portions from the earliest stage of development.

from depths as shallow as 5 feet (Abbott, 1958, p. 111) to 40 fathoms (Dall, 1889, p. 40; 1898, p. 649). Off the Florida coast, the general latitude in which most of our fossil species are found, it has been reported as occurring from 3 to 6 fathoms (Perry, 1940, p. 29; Perry and Schwengel, 1955, p. 35). In the Tulane University collections it is represented by a fresh valve dredged in 4 to 5 fathoms off Long Boat Key, near Sarasota, and by a worn valve from 18 fathoms off Highland Point, Monroe County. It is reported to prefer muddy to limy sand or pure sand bottoms occurring in most profusion in areas where marine grasses are growing (Hulings, 1955, p. 31; Abbott, 1958, p. 111; Warmke and Abbott, 1961, p. 159).

*Anadara biangulata* (Sowerby) [+ *Arca gordita* Lowe], the eastern Pacific species referred to *Caloosarca* by Olsson (1961, p. 98), has a rather similar bathymetric distribution. As reported by Hertlein and Strong (1943, p. 155-156) it ranges from 7 fathoms (Sowerby's type specimen) to 61 fathoms (off Costa Rica), being found in mud, sandy mud, shelly mud, muddy sand, sand, gravelly sand, crushed shells, and weeds. The majority of the records appear to be in the interval between 20 and 45 fathoms.

There is no evidence that could be interpreted as indicating any marked deviation from this general type of environmental preference for any of the fossil species referred to *Caloosarca* in this report. The matrix at all localities where the fossils are abundant consists predominantly of sand, usually with a small admixture of argillaceous or calcareous material. As noted in the discussion of *A. aequalitas* that species apparently preferred a somewhat larger lime content in the bottom sediments than did the contemporaneous *A. catasarca* which is most abundant in collections from localities in which the sediment is of a more pure sand composition. Furthermore, the associated molluscan faunas all accord well with a depth of water in the 5 to 40 fathom range.

## VIII. Locality Data

The following are Tulane University fossil locality numbers:

79. Caloosahatchee Fm. and unnamed post-Caloosahatchee formation mixed, spoil banks north and south side of Caloosahatchee River, at Ortona Lock (Sec. 27, T42S, R30E), Glades Co., Florida.
201. Unnamed post-Caloosahatchee formation, spoil banks at pit just south of Belle Glade, Palm Beach Co., Florida.
202. Caloosahatchee Fm., south bank of Caloosahatchee River, about two miles west of La Belle (SE ¼ Sec. 12, T43S, R28E), Hendry Co., Florida.
203. Caloosahatchee Fm., north bank of Caloosahatchee River, about two miles east of Fort Denaud (SW ¼ Sec. 11, T43S, R28E), Hendry Co., Florida.
283. Pinecrest Beds and unnamed post-Caloosahatchee formation mixed, spoil banks on cross canal 1.3 miles southwest of Port Charlotte Railroad Station (formerly Murdock), on Florida Highway 771 (Sec. 12, T40S, R21E), Charlotte Co., Florida.
519. Caloosahatchee Fm., Harney Pond Canal spoil banks, at Florida Highway 78, northwest side of Lake Okeechobee (NW ¼ Sec. 18, T40S, R33E), Glades Co., Florida.
523. Uppermost Pinecrest Beds (Brighton facies), and basal Caloosahatchee Fm., Harney Pond Canal spoil banks, six miles northwest of Florida Highway 78, Brighton Indian Reservation (NW ¼ Sec. 22, T39S, R32E), Glades Co., Florida.
527. Caloosahatchee Fm., north shore Lake Okeechobee, Pumping Station no. 127 (NE ¼ Sec. 35, T39S, R33E), Glades Co., Florida.
529b. Caloosahatchee Fm., north bank of Caloosahatchee River, about two miles west of La Belle (SE ¼ Sec. 12, T43S, R28E), Hendry Co., Florida.
532. Pinecrest Beds and Caloosahatchee Fm., mixed, spoil banks on cross canal 1¾ miles south of Florida Highway 771, 1.3 miles southwest of Port Charlotte Railroad Station (formerly Murdock) ( SE ¼ Sec. 24, T40S, R21E), Charlotte Co., Florida.
536. Caloosahatchee Fm., south bank of Caloosahatchee River about one mile east of La Belle (Sec. 3 & 4, T43S, R29E), Hendry Co., Florida. (Designated as type locality of the Caloosahatchee Formation by Olsson *in* Olsson and Petit, 1964, p. 519.)
539B. Caloosahatchee Fm., Shell Creek (lower beds), about eight miles east of Cleveland (Sec. 30, T40S, R25E), Charlotte Co., Florida.
541. Caloosahatchee Fm., Miami Canal spoil banks, two miles north of pumping station at Broward County line, Palm Beach Co., Florida.
558. Waccamaw Fm., borrow pits at north end of Crescent Beach Airport, Crescent Beach, Horry Co., South Carolina.
559. Waccamaw Fm., "Neill's Eddy Landing," south bank Cape Fear River near Acme, North Carolina.
579. Caloosahatchee Fm., Miami Canal spoil banks, four miles north of pumping station at Broward County line, Palm Beach Co., Florida.
580. Unnamed post-Caloosahatchee formation,

North New River Canal spoil banks, one mile south of South Bay, Palm Beach Co., Florida.

583. Caloosahatchee Fm., Miami Canal spoil banks, seven miles north of pumping station at Broward County line, Palm Beach Co., Fla.

725. Unnamed post-Caloosahatchee formation, North New River Canal spoil banks, three miles south of South Bay, at Okeelanta, Palm Beach Co., Florida.

727. Unnamed post-Caloosahatchee formation, borrow pits 2.2 miles east of U. S. Highway 27, 15 miles south of South Bay, Palm Beach Co., Florida.

729. Pinecrest Beds, spoil banks on west side of Kissimmee Canal and east side of Kissimmee River, approximately ½ mile south of U. S. Corps of Engineers Structure 65-D, (S ½ Sec. 33, T36S, R33E), Okeechobee Co., Florida.

731. Unnamed post-Caloosahatchee formation, West Palm Beach Canal spoil banks, at junction of U. S. Highway 441 and 98, seven miles west of Loxahatchee, Palm Beach Co., Florida.

732. Unnamed post-Caloosahatchee formation, borrow pits on Florida Highway 715, four miles north of Hillsborough Canal, at Belle Glade, Palm Beach Co., Florida.

733. Unnamed post-Caloosahatchee formation, North New River Canal spoil banks, one mile north of Florida Highway 80, at South Bay, Palm Beach Co., Florida.

736. Pinecrest Beds (Brighton facies), and Caloosahatchee Fm., mixed, spoil banks on south side of Florida Highway 70 and east side of Kissimmee River, Okeechobee Co., Florida.

740. Pinecrest Beds, levee fill, canal L-28, 3.6 miles west and 2.6 miles south of pumping station on Miami Canal at Broward-Palm Beach county line, Broward Co., Florida.

741. Pinecrest Beds and Caloosahatchee Fm., mixed, levee fill, canal L-28, 3.6 miles west and 3.6 miles south of pumping station on Miami Canal at Palm Beach county line, Broward Co., Florida.

742. Pinecrest Beds and Caloosahatchee Fm., mixed, levee fill, canal L-28, 3.6 miles west and 5.6 miles south of pumping station on Miami Canal at Broward-Palm Beach county line, Broward Co., Florida.

746. Unnamed post-Caloosahatchee formation, North New River Canal spoil banks, 5.3 miles north of pumping station at Broward county line on U. S. Highway 27, Palm Beach Co., Florida.

747. Unnamed post-Caloosahatchee formation, North New River Canal spoil banks, two miles south of South Bay, Palm Beach Co., Florida.

748. Unnamed post-Caloosahatchee formation, Lake Okeechobee levee, two miles north of South Bay, Palm Beach Co., Florida.

749. Caloosahatchee Fm. and unnamed post-Caloosahatchee formation mixed, borrow pits on south side of "Glades Airport," 1.3 miles south of Pahokee south city limits on Florida Highway 715, Palm Beach Co., Florida.

751. Unnamed post-Caloosahatchee formation, North New River Canal spoil banks, 1½ miles south of South Bay, Palm Beach Co., Florida.

755. Caloosahatchee Fm., Miami Canal spoil banks, 17.4 miles north of pumping station at Broward County line, Palm Beach Co., Florida.

759. Unnamed post-Caloosahatchee formation, spoil banks north side of Caloosahatchee River, two miles west of Ortona Lock (NE ¼ Sec. 29, T42S, R30E), Glades Co., Florida.

767. Caloosahatchee Fm. and unnamed post-Caloosahatchee formation mixed, spoil banks north side of Caloosahatchee River, five miles west of Ortona Lock (NW ¼ Sec. 36, T42S, R29E), Glades Co., Florida.

768. Caloosahatchee Fm. and unnamed post-Caloosahatchee formation mixed, spoil banks north side of Caloosahatchee River, 5½ miles west of Ortona Lock (NW ¼ Sec. 35, T42S, R29E), Glades Co., Florida.

770. Pinecrest Beds and Caloosahatchee Fm. mixed, spoil banks west side of Kissimmee River, 1½ to 3½ miles north of Florida Highway 70 (Secs. 10, 14, 15, and 28, T37S, R33E), Highlands Co., Florida.

788. Pinecrest Beds, Caloosahatchee Fm. and unnamed post-Caloosahatchee formation mixed, spoil banks at U-shaped canal, north side Florida Highway 771, 3.4 miles southwest of U.S. Highway 41 at Port Charlotte Railroad station (formerly Murdock, Fla.) (Sec. 15, T40S, R21E), Charlotte County, Florida.

792. Caloosahatchee Fm., borrow pits just west of Florida Highway 80, about two miles southwest of La Belle (SW ¼ Sec. 7, T43S, R29E), Hendry Co., Florida.

796. Pinecrest Beds, material exposed during construction of "Alligator Alley," 12.8 miles east of Florida Highway 29 (T49S, R32E), Collier Co., Florida.

797. Pinecrest Beds, material exposed during construction of "Alligator Alley," 13.3 miles east of Florida Highway 29 (T49S, R32E), Collier Co., Florida.

801. Caloosahatchee Fm., spoil banks south side of Caloosahatchee River, 2¾ miles west of Ortona Lock (NW ¼ Sec. 29, T42S, R30E), Glades Co., Florida.

802. Pinecrest Beds and Caloosahatchee Fm., mixed, spoil banks south side of Caloosahatchee River, 4¼ miles west of Ortona Lock (SE ¼ Sec. 25, T42S, R29E), Glades Co., Florida.

803. Unnamed post-Caloosahatchee formation, spoil banks south side of Caloosahatchee River, two miles west of Ortona Lock (NE ¼ Sec. 29, T42S, R30E), Glades Co., Florida.

816. Caloosahatchee Fm. and unnamed post-Caloosahatchee formation mixed, borrow pits, Cecil M. Webb Wildlife Management Area, 1.8 miles east of U. S. Highway 41 and 7.2 miles north of the Lee county line, Charlotte Co., Florida.

870. Waccamaw Fm., pits on east side of North Carolina Highway 130, 2.8 miles

north of Old Dock School, Old Dock, Columbus Co., North Carolina.
933. Pinecrest Beds, material exposed during construction of Alligator Alley, 21.5 miles east of Florida Highway 29, Collier County, Florida.
939. Caloosahatchee Fm. and unnamed post-Caloosahatchee formation (mixed), south side of Caloosahatchee River, 5.2 miles west of Ortona Lock (NW ½ Sec. 36, T42S, R29E) Glades Co., Florida.
953. Moín Fm. (type locality)—Moín Hill, in railroad cut and on side of adjacent road to Sandoval, Costa Rica. Locality is about 4.5 km west of Limón, Costa Rica.
954. Moín Fm., in hill cut immediately behind Standard Fruit Company box factory, just west of cemetery at Pueblo Nuevo, Costa Rica. Locality is about 2 km west of Limón, Costa Rica.
975. Pinecrest Beds and Caloosahatchee Fm., mixed, levee on north side of Caloosahatchee Canal, 0-.5 mile west of middle of former Lake Hicpochee, T42S, R32E (unmapped); Glades Co., Florida.
978. Unnamed post-Caloosahatchee formation, pit south of waterworks at South Bay, Palm Beach Co., Florida. Pit is approximately one mile north of Atlantic Coast Line Railroad.

Tulane University, Department of Geology, Recent localities:

R-9. Dredged in 3 to 5 fathoms off Longboat Key, Sarasota, Florida.
R-18. Beach collection, Virginia Key, Florida, near University of Miami Marine Laboratory.
R-35. Midden, near Jerico, Puerto Castilla, north of Trujillo, Honduras.
R-36. Beach collection, Atlantic side of Long Key, Florida Keys.
R-69. Beach and shallow water collection, Celestún, Yucatan, west side Yucatan Peninsula.
R-71. Beach collection, Punta Palmas, the northwest "corner" of Yucatan Peninsula.
R-74. Beach and shallow water collection, Isla Arenas, Campeche, about 16 miles south of Celestún, Yucatan.
R-76. Isla Cancun, Quintana Roo, first island south of Isla Mujeres. Beach and shore collection.
R-78. Chevihau, Yucatan (east of Telchac). Beach collection.
R-79. Telchac, Yucatan, beach collection [also known as Telchac Puerto].
R-82. Dzilam Bravo, Yucatan; beach and salt marsh coll.
R-100. *Anton Bruun* Cruise 10. Dredged off Duarte Cays, northwest of Porto Bello, Panama, 9°36.9′ N., 79°40.8′ W., from 140 to 160 feet. (42-49 meters)
R-105. *Hernan Cortez* Cruise 17, dredged off Highland Point, Monroe County, Florida, 81°23′ N., 25°33′ W., 18 fathoms.
R-109. Fill for refinery, Bahia las Minas, Isla Payardi, Panama. (Radiocarbon dated at 7000 years B. P.)
R-110. Whites Beach, near Porto Bello, Panama, beach coll.
R-115. Punta Ualakpich, north of Bahia de la Ascensión, Quintana Roo, Mexico. Beach and shallow water coll.
R-124. Bonacca (Guanaja) Island, Bay Islands, Honduras, beach collection, west side near south end of island (west of West Peak).
R-127. Bonacca (Guanaja) Island, Bay Islands, Honduras, beach and shallow water collection off "Columbus Beach," Pine Ridge Bight, northwest side of island.
R-128. Bonacca (Guanaja) Island, Bay Islands, Honduras, beach and shallow water coll. from west side of Michael Rock, northwest side of island.
R-130. Bonacca (Guanaja) Island, Bay Islands, Honduras, beach and shallow water coll., from area just west of Dunbar Rock, southeast side of island.
R-132. Bonacca (Guanaja) Island, Bay Islands, Honduras, beach collection from Shean Cays (village of Guanaja).
R-164. Isla Contoy, off Cabo Catoche, Quintana Roo, Mex. (second island north of Isla Mujeres). Beach and shallow water coll.

U. S. Geological Survey Tertiary Fossil Localities:

USGS 4275: Waccamaw Fm., Neill's Eddy Landing, Cape Fear River, 28 miles above Wilmington, North Carolina, at B. F. Keith's fertilizer plant.
USGS 4276: Waccamaw Fm., pit at B. F. Keith Fertilizer Plant, on Cape Fear River, North Carolina, 28 miles above Wilmington.
USGS 11152: Spoil bank, West Palm Beach Canal, 2 to 3 miles above Loxahatchee Post Office, Palm Beach Co., Florida.
USGS 13835: Marl pit one mile north of Bermont, Charlotte County, and about three miles south of Prairie Creek.
USGS 13975: Alligator Creek, Charlotte County, Florida about one-half mile above the railroad bridge.
USGS 14075: Material dredged from Caloosahatchee River, one mile west of Olga, Lee County, Florida (upper Miocene).
USGS 21257: Pinecrest beds, U. Miocene float near Acline pit; Sec. 29, T41S, R23E, about 1 mile southwest of Acline Station (Pit C. of Schroeder and Hoy sketch map, 1952, p. 73).
USGS 21907: Pinecrest beds, U. Miocene, same as loc. 21257.
USGS 21982: Unnamed post-Caloosahatchee formation, north of Moore Haven, Glades Co., Florida; float from road metal pits on west side of Fla. 78 about 4.5 miles north of intersection with U. S. 27.
USGS 21984: Unnamed post-Caloosahatchee formation, north of Moore Haven, Glades Co., Florida; east wall of pit at USGS loc. 21982.
USGS 22038: Unnamed post-Caloosahatchee formation, Port Mayaca, Martin Co., Florida. Float on south bank of St. Lucie Canal between U. S. 441 and Fla. East Coast Railroad bridge.
USGS 22039: Unnamed post-Caloosahatchee

formation, Port Mayaca, Martin Co., Florida, float from south bank of St. Lucie Canal at eastern boundary of Port Mayaca (east of loc. 22038).

USGS 22040: Unnamed post-Caloosahatchee formation, St. Lucie Canal, Martin Co., Florida; float from south bank about 2.5 miles east of Port Mayaca, north of cemetery.

USGS 22298: Pinecrest beds, U. Miocene pit at Acline, Charlotte Co., Florida (see loc. 21257) from 3.8 feet of shell marl exposed at base of section in west wall.

USGS 22299: Pinecrest beds, U. Miocene, base of bed at Acline Pit (see loc. 22298).

USGS 22445: "Caloosahatchee River, La Belle, Florida. Collected by J.L.M., May, 1928." (An old collection at U.S.N.M. Locality is probably in error. Fauna is in the main of Acline species, and of same preservation, but include some admixture of Pleistocene and Caloosahatchee material.

USGS 22742: Unnamed post-Caloosahatchee formation, South Prong of Alligator Creek, Charlotte Co., Florida. Float apparently from outcrops in stream northwest of bridge in NE ¼, Sec. 26, T40S, R23E, Cleveland quad.

USGS 22853: Unnamed post-Caloosahatchee formation, Shell Creek, Charlotte Co., Florida; outcrop of upper bed in gully cut into south bank of creek in extreme east side of Sec. 30, or west side of Sec. 29, T40S, R25E, Bermont quad.

USGS 22855: Unnamed post-Caloosahatchee formation, Shell Creek, Charlotte County, Florida; float from pits and cut on south side of creek in same area as loc. 22853.

USGS 23089: Unnamed post-Caloosahatchee formation, Shell Creek, Charlotte Co., Florida; first outcrops upstream from Mr. Washington's place.

USGS 23722: Caloosahatchee Fm., spoil bank, west side of Miami Canal, about 9.3-9.9 miles south of Lake Harbor, Palm Beach Co., Florida (= TU 755).

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# NOTE ON THE OCCURRENCE OF *PANOPEA BITRUNCATA* (Conrad)

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In 1872 Conrad described *Glycimeris bitruncata* (p. 216, pl. 7, fig. 1), referring the species to "*Glycimeris* Klein. H. and A. Adams."* At that time Conrad noted: "This interesting shell was sent to the Academy by Dr. Yarrow from Fort Macon [North Carolina]. I suppose it to be a recent shell on account of its polish, and part of the unaltered ligament remaining. Two specimens were found. It is the only recent species of *Glycimeris* inhabiting the coasts of [eastern] North America. . . ." Conrad's figure of the type specimen, a right valve, reveals that it is somewhat distorted posteriorly, as may be observed from the growth lines on the outer margin of the valve. The specimen here illustrated (text fig. 1) shows, more correctly, the shape of the adult shell.

In the years subsequent to its original description the species has been found, as isolated valves, from North Carolina to Florida and in the Gulf of Mexico from the vicinity of Tampa (Dall, 1898, p. 832), and "Crooked Island, off St. Andrews Sound, Calhoun [= Bay] Co., Florida" (Vanatta, 1903, p. 757). Dall (1898, p. 832) notes that it "has not yet been found in a definitely fossil state" and Abbott (1954, p. 454) adds: "Dead valves are rarely found, and I have never seen a live specimen. Possibly extinct."

Recently, while collecting fossils from the diapiric "Mudlump 90" to the west of the entrance to the South Pass of the Mississippi River delta, two specimens with paired valves, plus two separate valves and fragments of at least eight others were secured from the "shell bed" that occurs between "Clay units I and II" (see Morgan, Coleman and Gagliano, 1968, p. 151, 152, and text figs. 8, 9). According to these authors (p. 152) two radiocarbon datings of molluscan and foraminiferal materials from this bed "are comparable and yield an age of 15,500 yr B. P. . . . [and] the fauna suggests water depths of 100-200 ft during the time of accumulation."

The occurrence of this species in the mudlump fauna, while not certainly settling the problem as to whether it is, or is not presently extinct, clearly indicates that, unlike its Pacific coast analogue, *P. generosa* Gould, which occurs in mud in waters of only two or three feet depth (Abbott, 1954, p. 454), *P. bitruncata* is a deep water species. Its deeply burrowing habit would preclude its being taken by the usual dredging or trawling methods, and only under unusual and rare circumstances would it be washed out of the mud and transported to shore by wave or current action. The fact that it does so occur, strongly suggests that it may be a rather abundant element in the deeper, offshore faunas.

The writer wishes to express his great indebtedness to the officials of the Chevron Oil Company who provided plane and helicopter transportation to the mudlump, making it possible to collect the faunas, and especially to Mr. Wilburn H. Akers who made all necessary arrangements.

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* The "*Glycimeris* Klein" of H. and A. Adams (1856, p. 350) is a synonym of *Glycimeris* Lamarck, 1799 (not of Lamarck, 1801, = *Cyrtodaria* Reuss, 1801). Since 1898, when Dall revived the name *Glycymeris* Da Costa, 1778, for the group of species previously referred to the genus *Pectunculus* Lamarck, 1799 (*non* Da Costa, 1778, Veneridae), the name *Glycimeris* Lamarck, 1799, has largely been replaced by *Panopea* (or *Panope*) Menard, 1807. Prior to the publication of the "International Code of Zoological Nomenclature" in 1961, most authors held that *Glycimeris* Lamarck, 1799 and 1801 were both homonyms of *Glycymeris* Da Costa, especially since the latter name had been widely misspelled as "*Glycimeris*." However, Article 56 (a) of the International Code of 1961 specifies that differences of a single letter are sufficient to prevent names entering into homonymy; thus *Glycimeris* Lamarck, 1799, is the correct generic name for the species now almost universally referred to *Panopea*. Concerned with the vast amount of confusion that would ensue in molluscan nomenclature if this change had to be made, the writer and the late Dr. L. R. Cox of the British Museum (Natural History) petitioned the International Commission to use its plenary powers to validate the established and customary nomenclature. This petition, which was published in the "Bulletin of Zoological Nomenclature," vol. 18, pt. 3, p. 184-188, in June, 1961, has to this date not been acted upon by the Commission!

Figure 1. *Panopea bitruncata* (Conrad). Right valve of largest pair in collection, × 0.9. The shell was broken by movement of the enclosing mud during its diapiric extrusion through the overlying deltaic sediments. Locality TU 977, Mudlump no. 90, off South Pass, Mississippi River delta.

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July 16, 1969

# REVIEWS

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LECTURES ON GEOLOGY, by John Walker; edited with notes by Harold W. Scott. Published by University of Chicago Press, Chicago and London, 1966, xlvi + 280 pp., $8.50

Geology, the youngest science, was conceived in the city of Edinburgh early in the fourth quarter of the eighteenth century. It was nurtured within one of the most remarkable intellectual climates ever formed, *The Edinburgh Circle.* Among the members of this circle were: Robert Adam, architect; Joseph Black, chemist; John Clerk, sen. and jun. of Eldin; Adam Ferguson, philosopher; Sir James Hall, experimental chemist; James Hutton, geologist; John Playfair, mathematician and physicist; Adam Smith, writer; and Dugald Stewart, philosopher.

In the spring of 1802, John Playfair made the first attempt to delineate the singular factors which contribute to the unique position of geology among the sciences; stating:

> ". . . on account of the complexness of its subject, geology is the youngest of the sciences."

Playfair was well qualified to comment; he was present at the birth of geology, he was there throughout the formative years of the fledgling science, and he became its foster father when Hutton expired in 1797. His belief that James Hutton was of first importance is unmistakable.

In *Lectures on Geology* the claim is made that the "real father of geological teaching" was John Walker, regius professor of natural history at the University of Edinburgh and a lesser known contemporary of the widely recognized "Founders of Geology," namely James Hutton, John Playfair and Sir James Hall. In fact, extant registration lists reveal that Playfair, Hall and Robert Jameson were numbered among those who attended Walker's lectures at the University. It seems certain that he had some effect on the thinking of these three men, but the conspicuous absence of James Hutton's name from these lists or any other evidence of direct interchange between Walker and Hutton is most significant. If we focus our attention on actual innovations in fundamental geological thought rather than on commentary or lectures on geology and subjects related to geology, the answer emerges clearly. James Hutton's perception of the *vast continuum* and his search for and discovery of field evidence for his concept of the *unconformity* remain unequalled as contributions to the basic theory of geology during his lifetime. After analytical comparison of the work of Hutton and that of Walker, it seems to this observer that James Hutton's position in the history of geology becomes stronger and more remarkable.

John Walker's *Lectures on Geology* are of great interest and this book thoroughly documents his significance as an early *teacher* of natural history and member of the Edinburgh scientific community. We are grateful to Professor Scott for publishing the *Lectures* and making them available for general study and evaluation.

JAMES HUTTON—THE FOUNDER OF MODERN GEOLOGY, by Edward Battersby Bailey. Published by Elsevier Publishing Co. Ltd., Amsterdam, London and New York, 1967, xii + 161 pp., $9.00

This book is a definitive study of Hutton's three volume work, *Theory of the Earth*, chapter by chapter, with commentary and explanatory re-statement where Hutton's prose was too lengthy or obscure. Sir Edward's intimate knowledge of the geology of Scotland makes his commentaries on Hutton's deductions (and on the many difficulties encountered by Hutton in developing his interpretations of basic geological problems) most authoritative and reveals the brilliant quality of Hutton's observations, arguments and conclusions. From this analysis Hutton emerges with even greater significance to the history of geology than before. Everyone interested in the early development of geologic thought should own and study this volume.

STUDIES ON GLACIERS, preceded by the DISCOURSE OF NEUCHÂTEL, by Louis Agassiz translated and edited by Albert V. Carozzi. Published by Hafner Publishing Company, New York and London, 1967, lxxi + 213 + x pp., 18 plates (14 with overlay sketches), $27.50

This volume provides the first English translations of Agassiz's classic *Etudes sur les Glaciers* and his momentous presidential address before the Société Helvétique des Sciences Naturelles at Neuchâtel on July 24, 1837, in which he first disclosed his ideas about glaciers. The text is preceded by a detailed description of the famous controversy which followed publication of the book and ended, after a bitter and powerful struggle, with general acceptance of Agassiz's concept of an Ice-age. The book and the atlas of plates with overlay sketches is handsomely printed and quite pleasing.

ON THE ORIGIN OF SPRINGS, by Pierre Perrault; translated by Aurele LaRocque. Published by Hafner Publishing Company, New York and London, 1967, vi + 209 pp., $15.00

This translation of the rare "first book on hydrology" is a welcome addition to the historical literature of the geological sciences. Perrault was the first to show that rainfall is sufficient cause for the flow of rivers and springs, making this volume of primary importance to the history of hydrology. Its usefulness is enhanced by the translator's annotations and the index which is appended.

CARBONATE ROCKS, edited by George V. Chilingar, Harold J. Bissell and Rhodes W. Fairbridge. Published by Elsevier Publishing Company, Amsterdam, London and New York, 1967; part A, v + 471 pp.; part B, ix + 413 pp.; each volume, $27.00

These two volumes comprise part nine of the *Developments in Sedimentology* series. The work is the first comprehensive treatment in English of this extremely important group of rocks which constitute 10 to 15% of the sedimentary rocks of the crust. The first part concentrates mainly on the origin, occurrence and classification of carbonate rocks, including sites and characteristics of modern carbonate deposition, carbonates as oil-reservoir rocks, and carbonates as climatic indicators. The second part stresses physicochemical aspects of the carbonate rocks, especially the low-temperature types. It includes sections on the origin of petroleum in carbonate rocks, and the physical properties and economic uses of the carbonate rocks and minerals.

ESSAYS IN GEOMORPHOLOGY, edited by G. H. Dury. Published by American Elsevier Publishing Company, Inc., New York, 1966, xi + 404 pp., $14.00

Nine essays by ten leading geomorphologists are included. The unifying theme of the symposium is the systematic approach to morphological problems. Six essays relate to specific study areas; the last three are wholly thematic.

TUFFLAVAS AND IGNIMBRITES: A Survey of Soviet Studies, edited by Earl F. Cook. Published by American Elsevier Publishing Company, Inc., New York, 1966, xii + 212 pp., $7.00

A collection of thirty recent papers by outstanding Soviet scientists on Tufflavas and Ignimbrites is presented in this volume, freely edited and amended by Professor Cook, who is chairman of the Earth Sciences Committee of the National Academy of Sciences. The translations from the Russian are by Miriam Carty.

THE ORIGIN OF CONTINENTS AND OCEANS, by Alfred Wegener. Published by Dover Publications, Inc., New York, 1966, x + 246 pp., $2.00

This is a *new* English translation of Alfred Wegener's classic book, first published in 1915, and one of the most revolutionary books in the history of science. This edition makes available for the first time the translation of the fourth fully revised German edition of 1929.

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# DISSOLUTION OF MOLLUSCAN CALCITE BY THE ATTACHED FORAMINIFER *VASIGLOBULINA*, NEW GENUS (VASIGLOBULININAE, NEW SUBFAMILY)

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## I. ABSTRACT

The new foraminiferal genus *Vasiglobulina* comprises polymorphine species which possess an apertural system of hollow tubules radiating outward from the distal end of the final chamber lumen to the exterior surface of the test. The type species, *Vasiglobulina alabamensis* (Cushman and McGlamery), occurs in Gulf Coast sedimentary rocks which were deposited under shallow marine conditions during the upper Eocene to lower Miocene Epochs. It is ornamented by exterior spines which penetrate mollusc fragments, establishing a unique mode of permanent epifaunal attachment. These unusual morphological features furnish the bases for significant paleoecological and functional inferences.

Five previously described species from Gulf Coast and European Tertiary localities are assigned to *Vasiglobulina,* establishing its known geologic range as upper Eocene to Pliocene.

## II. INTRODUCTION

Benthonic Foraminifera are attached to the substratum in a variety of ways. They may be vagile grazers that temporarily at-

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tach themselves by pseudopodia (Arnold, 1964) or sessile forms permanently bound by anastomosing pseudopodial strands to loose sediment (Nyholm, 1952). Other forms are attached pseudopodially to living seaweeds (Bock, 1968), corals (Emiliani, 1951), molluscs (Todd, 1965), other organisms (Nyholm, 1961), and various inanimate objects. Permanent attachment by means of an encrusting cement is well known in living forms such as *Cibicides* (Nyholm, 1961), *Nubecularia,* and *Calcituba,* and in fossil forms such as *Webbinella* (Loeblich and Tappan, 1957). Some fossil forms, such as *Planorbulinella,* may be recognized as having been attached in the living state by the presence of a flattened or irregularly contorted test that reflects the contour of the substratum. Pokorný (1963) reports that certain species of the Buliminidae attach themselves by terminal spines. Some species live in the empty tests of other foraminifera or in worm tubes (Nyholm, 1953). A few are believed to be parasitic on other foraminifera (Le Calvez, 1947), and at least one species is epizoic on a bivalve (Todd, 1965).

The present work describes a new mode of attachment among the foraminifera (Polymorphinidae) which involves partial or complete penetration of molluscan shell fragments by acicular spines protruding from the exterior surface of the foraminiferal test. Such a peculiar means of attachment has not been documented in the foraminiferal literature, although some polymorphine species have been reported attached to calcareous fragments and quartz grains by extensions of the test (*e.g.,* Cushman, 1922a; Fuchs, 1967). Some significant additions to to the numerous known functional responses of foraminiferal pseudopodia are inferred from this manner of permanent attachment.

Forms with this unusual attachment also possess a singular modification of the usual polymorphinid aperture which consists of radiating slits. This unique aperture is a system of hollow tubules radiating from the distal end of the final chamber lumen to the exterior surface of the test.

In order to place this group of species within the taxonomic framework established by Loeblich and Tappan (1964), the new genus *Vasiglobulina* is erected. It is placed within the Nodosariacea, family Polymorphinidae, by modifying the definition of a radiate aperture given by Loeblich and Tappan (1964). It now becomes an "Opening associated with numerous diverging slits [or hollow tubules] . . . "* As no existing subfamily will accommodate the genus, the writer proposes the new subfamily, Vasiglobulininae.

* Phrases in brackets are additions to the descriptions given by Loeblich and Tappan, 1964.

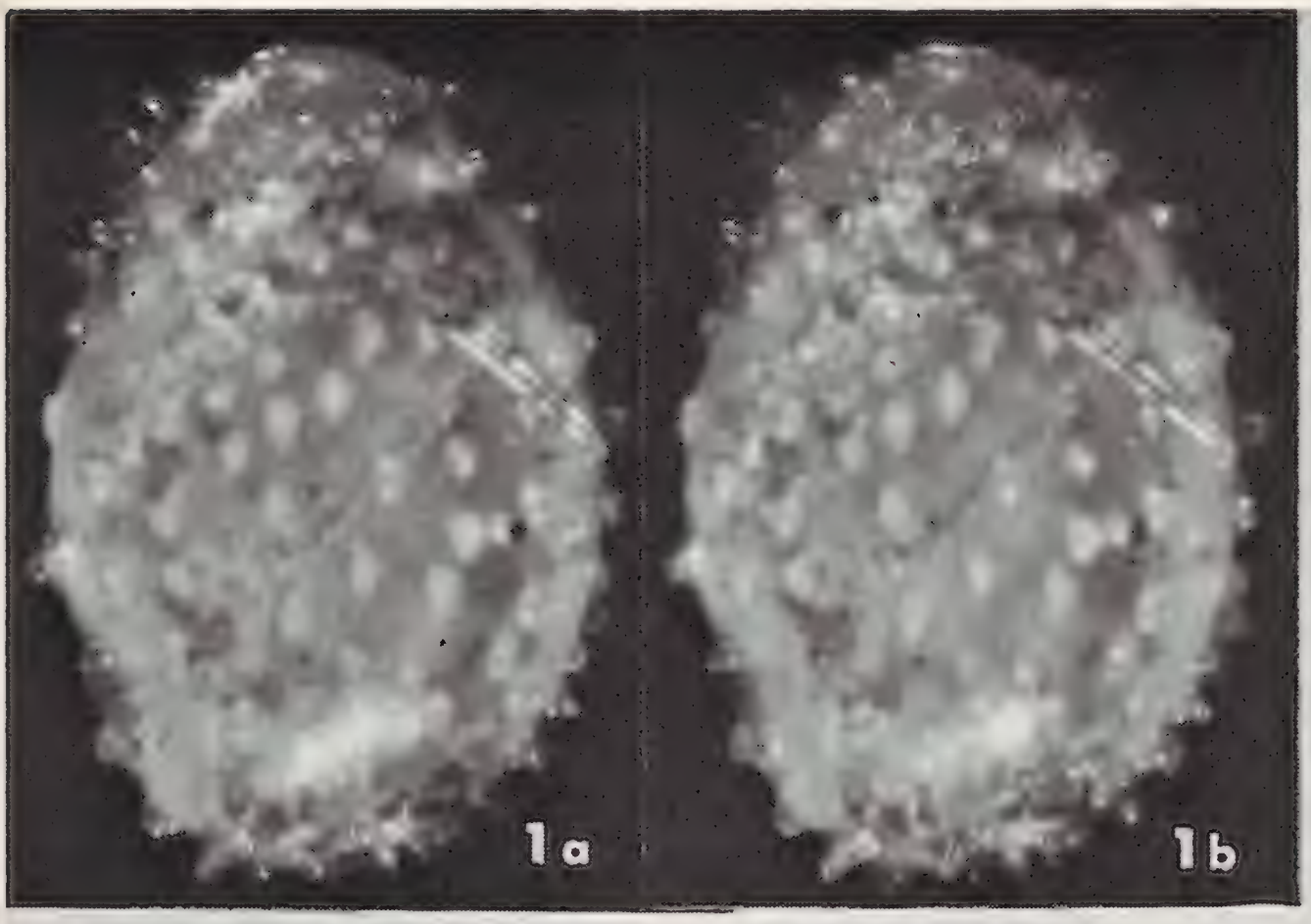
→

PLATE 1

*Vasiglobulina alabamensis* (Cushman and McGlamery). All specimens from the Oligocene Chickasawhay Formation near Millry, Alabama. Apertural ends are at the top.

Figures

1 Stereopair of 5-chambered holotype; note flattened test and distinct final suture crossing test diagonally. X 90
2 Apertural view of holotype; transmitted light. X 90
3 Paratype A; 4 chambers. X 90
4 Apertural view of holotype showing radiating tubules; focus below upper surface of apertural mound; transmitted light. X 420
5 Paratype B; 5 chambers; note smooth surface of reduced final chamber. X 90
6 Spine of paratype C showing distal thickening; note irregularly broken distal end. X 420
7 Paratype C showing well preserved long spines; 4 chambers. X 90
8 Spine of paratype C; note distal tapering. X 420
9 Spine of paratype C; note slight thickening of distal end and flat, evenly broken tip. X 420



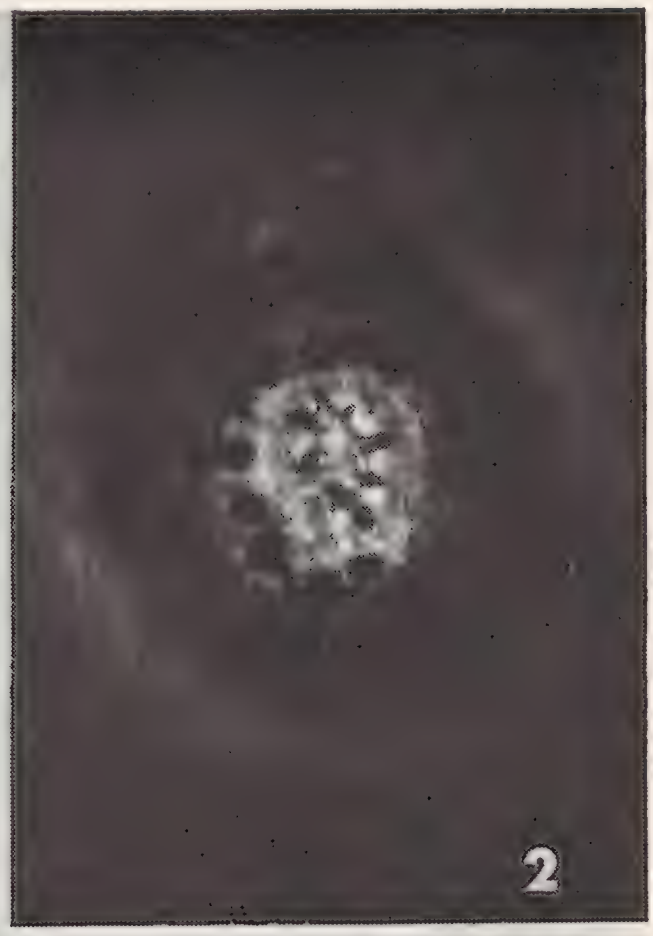
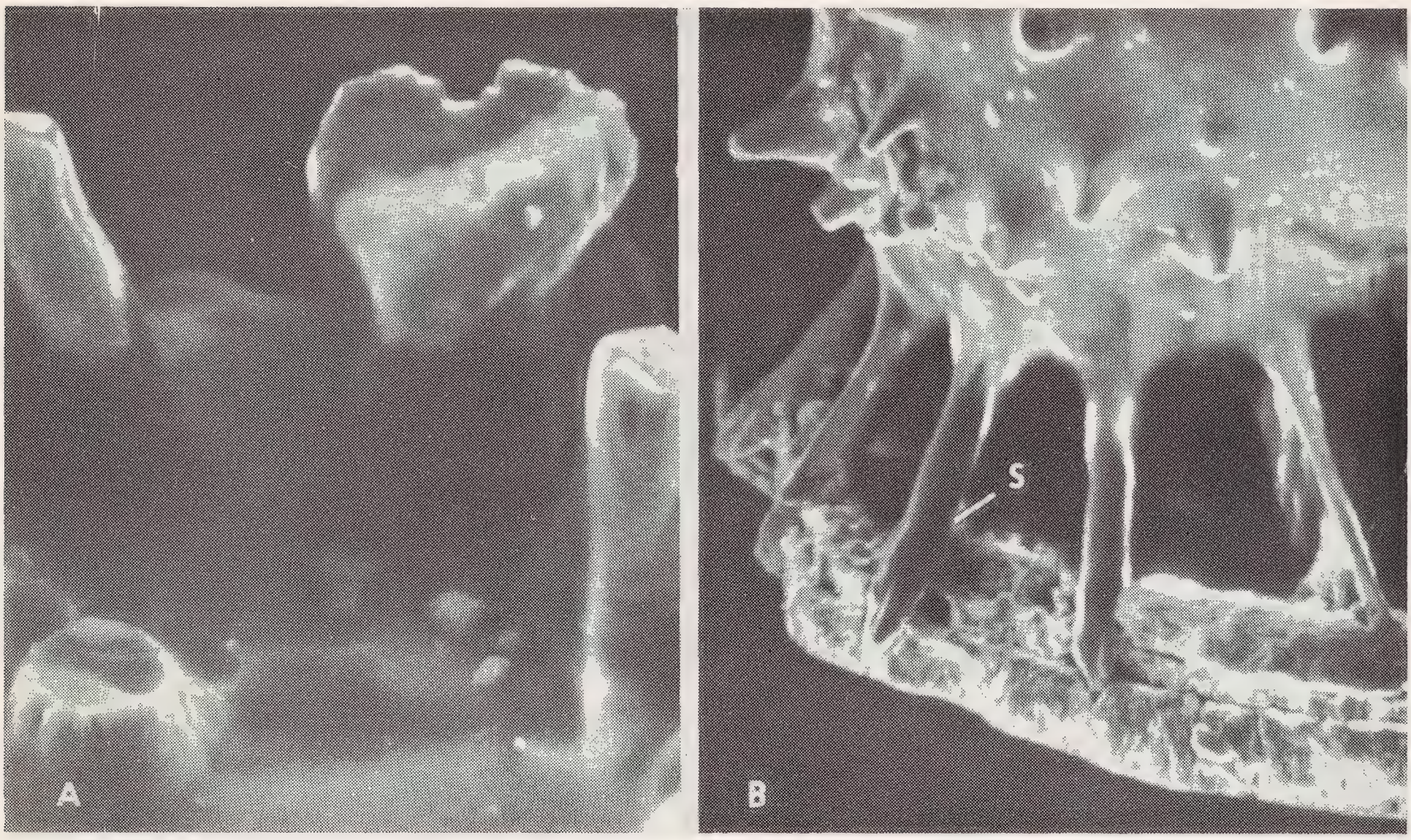



PLATE 1




TEXT FIGURE 1

Scanning electron photomicrographs of *Vasiglobulina alabamensis* spines. A. Note distal thickening of spine at upper right; note longitudinal grooves on broken spine base at lower left; X 1000. B. Spines of hypotype B penetrating mollusc fragment; note distal thickening of spine ("s") within the mollusc fragment and the longitudinal grooves near the tip; X 300.

## III. SYSTEMATIC PALEONTOLOGY

Order FORAMINIFERIDA Eichwald, 1830

Suborder ROTALIINA Delage and Hérouard, 1896

Superfamily NODOSARIACEA, Ehrenberg, 1838

Family POLYMORPHINIDAE d'Orbigny, 1839

Test multilocular, chambers in spiral or sigmoidal coil about longitudinal axis of growth, or biserial, or uniserial, typically somewhat overlapping; [free or attached;]* apertures all develop in the same direction, terminal, radiate.

Subfamily VASIGLOBULININAE Poag, subf. n.

Test ovoid or pyriform, generally attached by spines; aperture a system of hollow tubules radiating outward from the distal end of the final chamber lumen to the exterior surface of the test.

Genus VASIGLOBULINA Poag, gen. n.

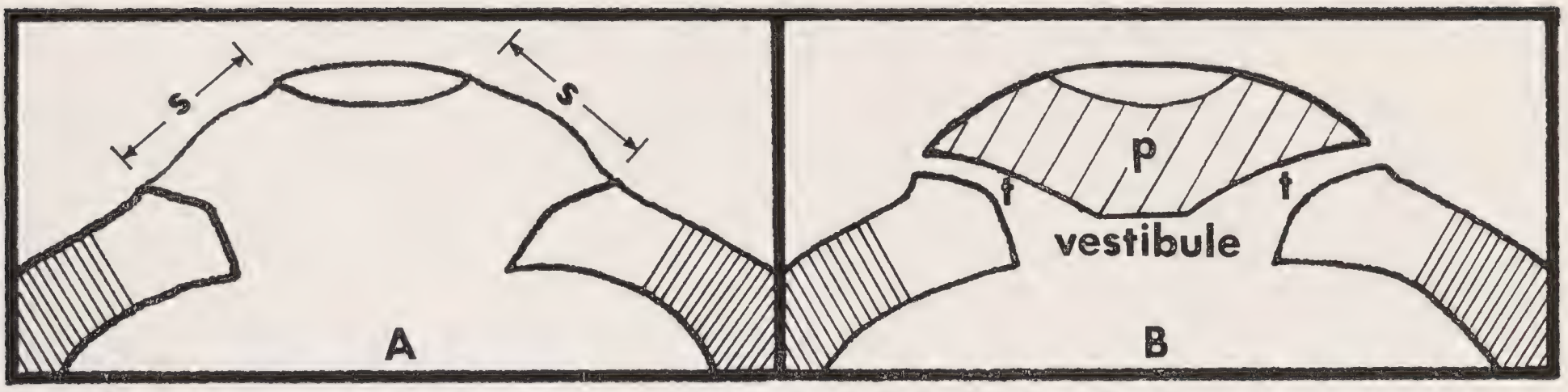
Test primarily attached by spines, calcareous, hyaline, with finely perforate monolamellar walls of optically radial calcite; chambers few, embracing, rapidly increasing in size as added; chambers added to spiral coil at approximately 144° intervals; wall generally spinose; aperture a system of hollow tubules radiating outward from a common vestibule at the distal end of the final chamber lumen to the exterior surface of the test.

Type species: *Globulina alabamensis* Cushman and McGlamery, 1939.

Etymology: From Latin *vas,* meaning duct and *Globulina,* a related foraminiferal genus; the name refers to the tubular aperture.

Material: *Vasiglobulina alabamensis* (Cushman and McGlamery), 1939

1) Paynes Hammock Formation on Chickasawhay River near Waynesboro, Mississippi—2 specimens
2) Chickasawhay Formation
   a) Taylor Mill Creek near Waynesboro, Mississippi—84 specimens
   b) Millry, Alabama—11 specimens
3) Byram Formation at type locality, Byram, Mississippi—1 specimen
4) Mint Spring Marl at Mint Spring Bayou, Mississippi—3 specimens




TEXT FIGURE 2

Diagrammatic illustration of transition from slit-like polymorphinid aperture to tubular vasiglobulinid aperture; A = polymorphinid aperture; s = slit openings; B = vasiglobulinid aperture; p = plug of calcite filling most of apertural cavity and blocking distal portions of elongate slits; t = tubular passages radiating from vestibule to exterior surface of test.

5) Red Bluff Clay
   a) Hiwannee, Mississippi—7 specimens
   b) Little Stave Creek, Alabama—2 specimens

*Vasiglobulina tuberculata* (d'Orbigny), 1846
1) *Amphistegina* Marl near Vienna, Austria—2 specimens
2) Pliocene near Piacenza, Italy—2 specimens probably conspecific

*Vasiglobulina striata* (Egger), 1857
1) Miocene near Ortenburg, L. Bavaria—1 specimen
2) Pliocene near Piacenza, Italy—6 specimens

*Vasiglobulina variata* (Jones, Parker, and Brady), 1866
1) Coralline Crag, Sutton, Suffolk, England—3 specimens

*Vasiglobulina punctata* (d'Orbigny), 1846
1) Coralline Crag, Sutton, Suffolk, England—13 specimens
2) Pliocene near Piacenza, Italy—8 specimens
3) Stampien at Jeurre, France—4 specimens

Smooth forms belonging to *"Globulina gibba"* group:
1) Pliocene near Piacenza, Italy—3 specimens
2) Pliocene near Cecina, Italy—2 specimens
3) Chickasawhay Formation—7 specimens

Remarks: The radiating tubular apertural system is present in all the strongly spinose polymorphine forms observed. Several smooth specimens from the Pliocene near Piacenza, and Cecina, Italy, and in the Chickasawhay samples from Taylor Mill Creek, Mississippi, also have such an aperture (pl. 10, figs. 7, 9, 10, 12). The morphology of these smooth forms is otherwise that of the *"Globulina gibba"* group.

## IV. DESCRIPTIVE MORPHOLOGY

The type species of *Vasiglobulina* is *Vasiglobulina alabamensis* (Cushman and McGlamery), a foraminifer of moderate size with an ovoid or pyriform shape. The base is generally broadly rounded, the apertural end is tapered, and the outline is circular to flatly ovate in transverse section (pl. 1, figs. 1,3,5,7; pl. 8, figs. 1-10). The finely perforate wall (pl. 3, fig. 3; pl. 5, fig. 7) is constructed of calcite crystals with their C-axes predominantly radially oriented, as indicated by the dark extinction figure produced under crossed nicols (pl. 3, fig. 5).

*Spines*

Most of the outer surface is ornamented by randomly placed spines, of large diameter, variable length, and generally bluntly broken (text figure 1A; pl. 1, figs. 6,8,9; pl. 4, figs. 1-12). The several attached specimens that have been observed display short or long spines, some of which partially or completely penetrate the molluscan fragments to which they attach (text fig. 1B; pl. 2, figs. 1-8; pl. 3, figs. 6,7,8). The spines pass through the mollusc shells without disturbing the normal molluscan calcite lamellae except to produce dissolution cavities into which the spines are inserted (text fig. 1B; pl. 2, fig. 5; pl. 5, fig. 1). This is in contrast to the anomalous mounds of calcite on the shells of living molluscs caused by the epizoic *Rosalina carnivora* (Todd, 1965).

Most spines taper as they elongate (pl. 4, figs. 2,3,4,8), but some have an hourglass shape that results from distal thickening within the mollusc shell (text fig. 3; pl. 1, figs. 6,9; pl. 2, fig. 2; pl. 4, figs. 5,6,11,12; pl. 5, fig. 1). All spines examined appear to be non-perforate calcite (pl. 4, figs. 2-14; pl. 5, fig. 7).

Under crossed nicols, the spines do not extinguish in transverse section (pl. 3, fig. 4; pl. 4, figs. 13,14). In longitudinal section, however, they extinguish almost completely or produce broad transverse bands of color (pl. 4, fig. 7). They are, therefore, in optical continuity, and may be single crystals or groups of similarly oriented crystals in which the C-axes are perpendicular to the long axis of the spine and to the C-axes of the crystals in the test wall proper. Wood (1949) and Lipps (1966) have described the spines of certain planktonic species as single crystals of calcite, but Towe and Cifelli (1967) have discussed the ambiguities involved in the concept of single crystals and have cautioned against the uncritical use of wall structural terms based on optical observations.

Some spines extend through all the calcite lamellae of the test wall, in the juvenile as well as adult portions of the test (pl. 5, figs. 5-7); others are formed from only the final lamella. Although layering is apparently lacking in the spines, the general configuration in longitudinal section (pl. 5, fig. 7) is similar to that of inflational pillars ascribed to the Rotaliidae by Smout (1954; *cf.* pl. 19, figs. 11,12).

A broken hourglass-shaped spine on unattached specimens indicates a point of previous attachment (pl. 4, figs. 1,5,6,11; pl. 9, fig. 6). Although the site of attachment may vary, it is most commonly along the flattened side of the test, subparallel to the axis of coiling (pl. 2, figs. 1,4,7; pl. 9, fig. 4).

### *Chamber Arrangement*

The test generally comprises 4 to 5 visible chambers, which increase rapidly in size as added (pl. 8, figs. 1-10). The coiling pattern is spiral, with chambers added at intervals of approximately 144°. Each succeeding chamber extensively embraces one or more of those preceding it. The initial chamber is often difficult to observe because it is enveloped almost completely by the succeeding chambers. A reduced final chamber may be present (pl. 1, fig. 5), a variation apparently characteristic of many foraminiferal species. Intercameral sutures are narrow; those separating the first three or four chambers are flush with the surface or slightly depressed (pl. 8, fig. 4). The final intercameral suture, however, may be

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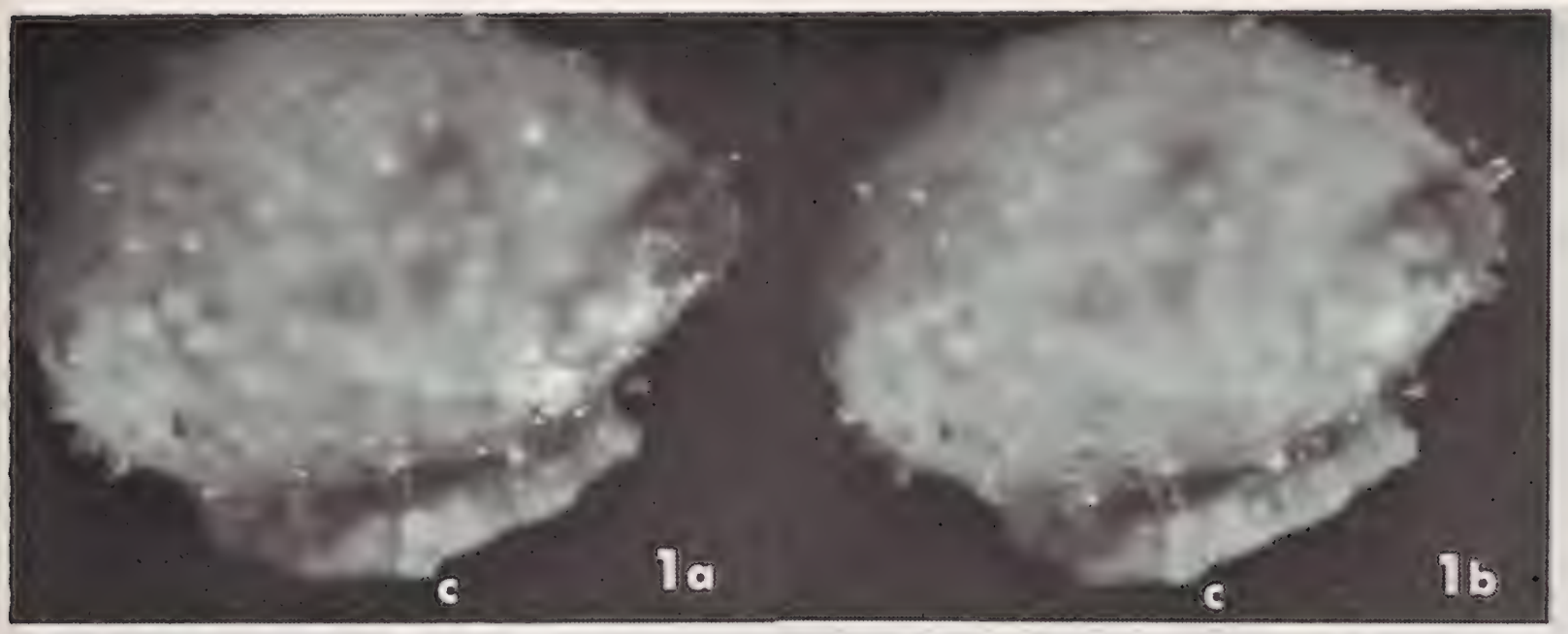
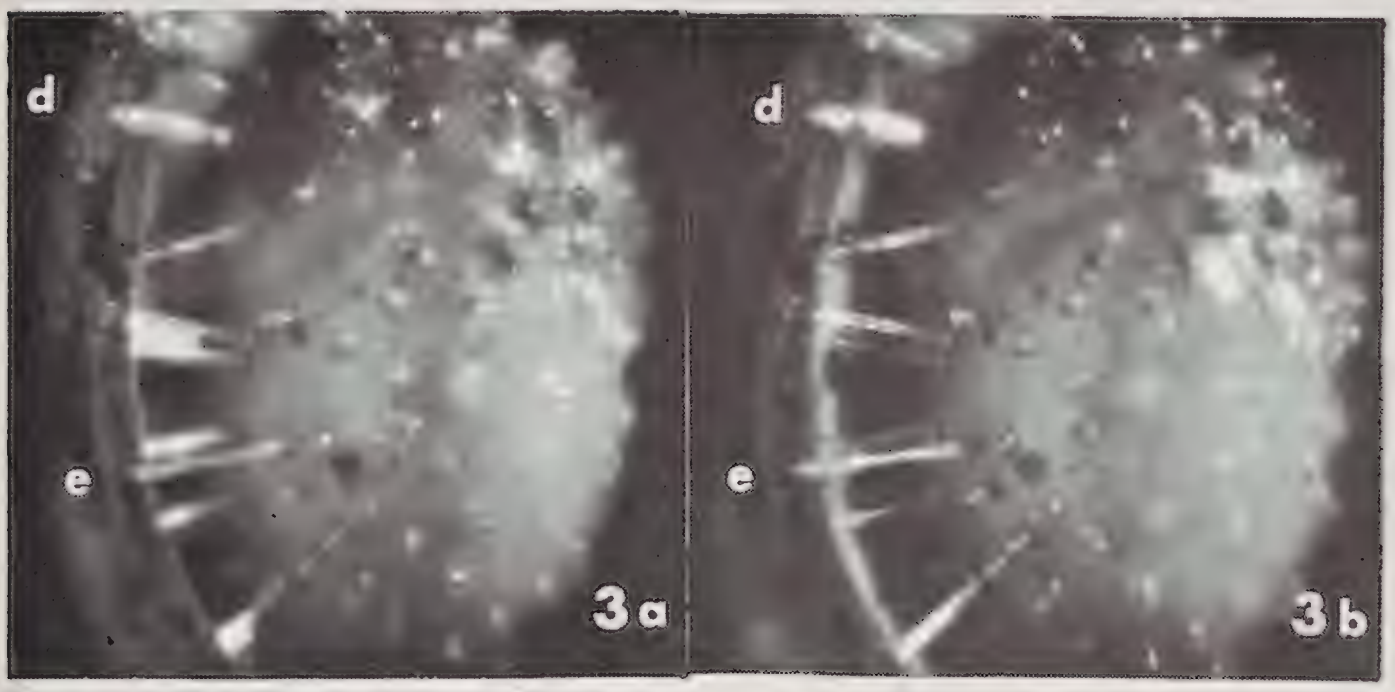
## Plate 2

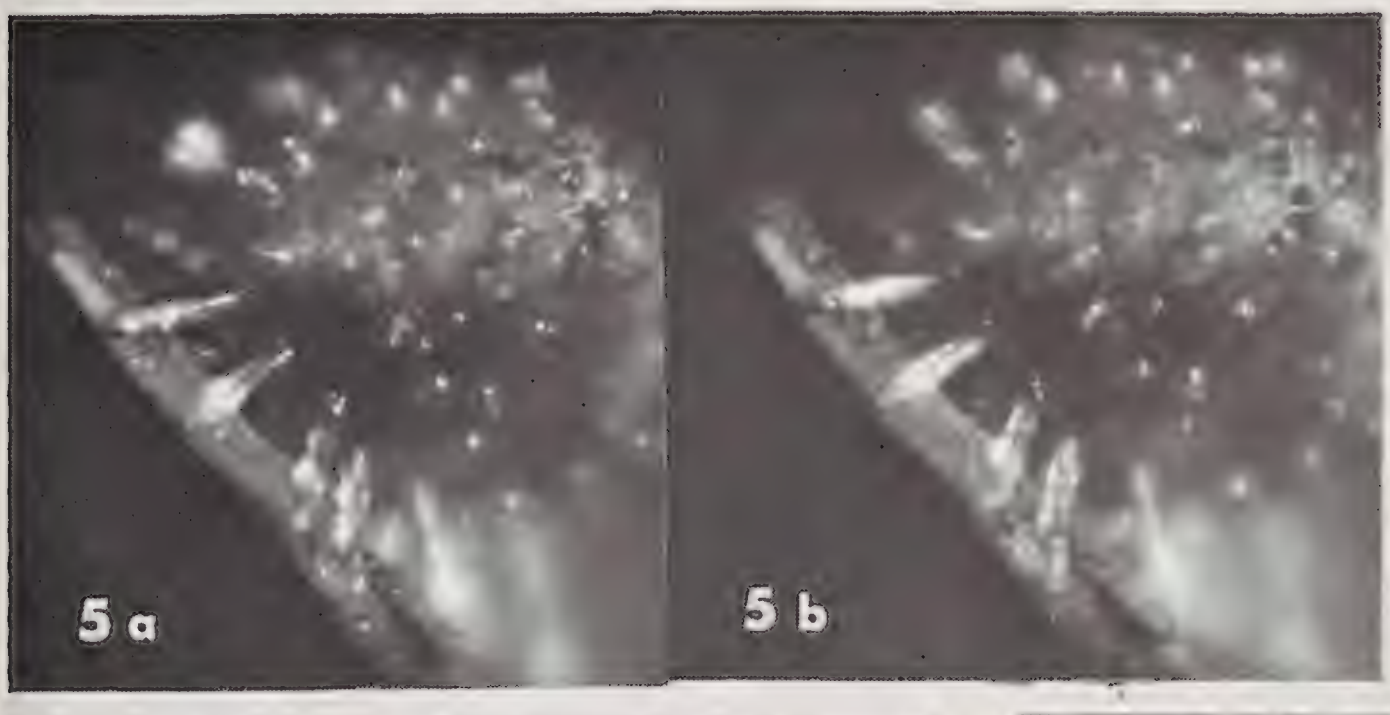
Figures

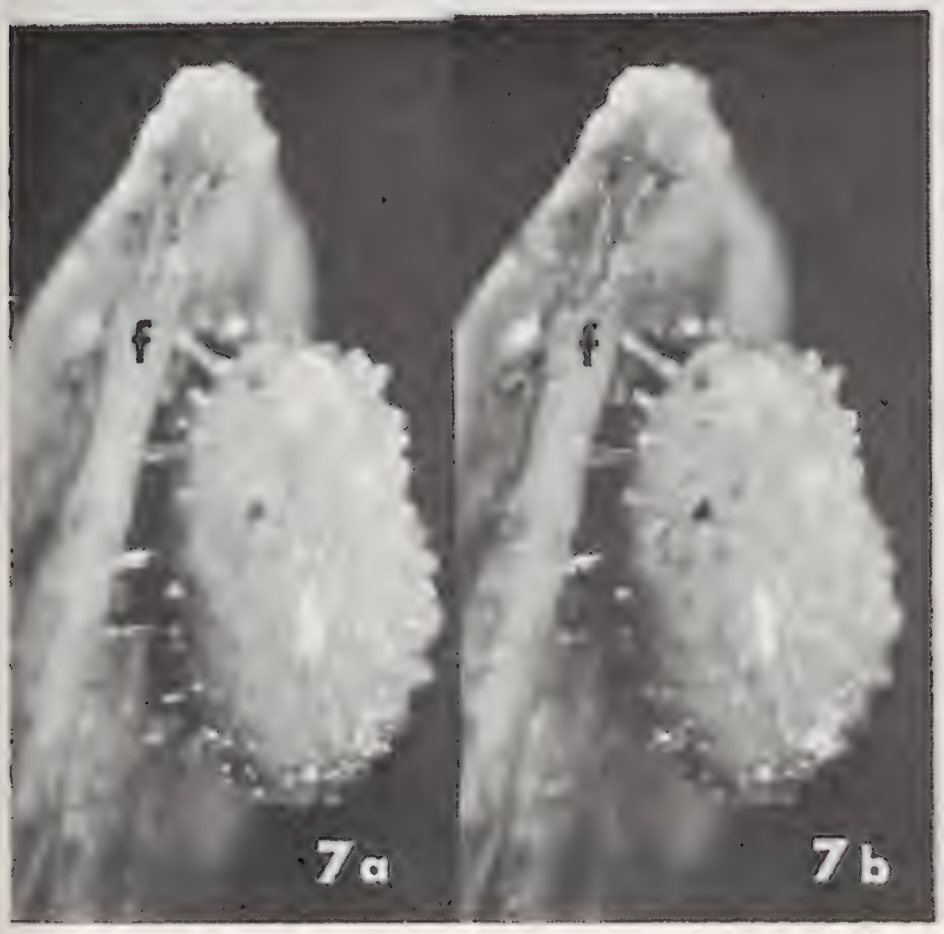
*Vasiglobulina alabamensis* (Cushman and McGlamery). Attached specimens from the Chickasawhay Formation at Taylor Mill Creek, near Waynesboro, Mississippi.

1 Stereopair of hypotype A, U.S.N.M. No. 687806. Note close attachment to interior surface of mollusc, and thickening of spine "c" after entering fragment; 4 chambers. X 90
2 Hourglass-shaped spine "f" of holotype C. X 180
3 Stereopair of hypotype B, U.S.N.M. No. 687807. Note length of slender attaching spines; note spine tips at "d" and "e" entering edge of mollusc. X 90
4 Hypotype B showing attachment to concave inner surface of mollusc fragment; 4 chambers; apertural end at bottom. X 52.5
5 Stereopair of basal view of hypotype B showing spines penetrating edge of mollusc fragment. X 90
6 Hypotype C, U.S.N.M. No. 687808. Note attachment to outer ornamented surface of *Pecten* fragment; 4 chambers; aperture at top. X 35
7 Stereopair of hypotype C showing hourglass-shaped spine at "f"; apertural end at bottom. X 52.5
8 Stereopair of hypotype C. Note hourglass-shaped spine "f." X 90









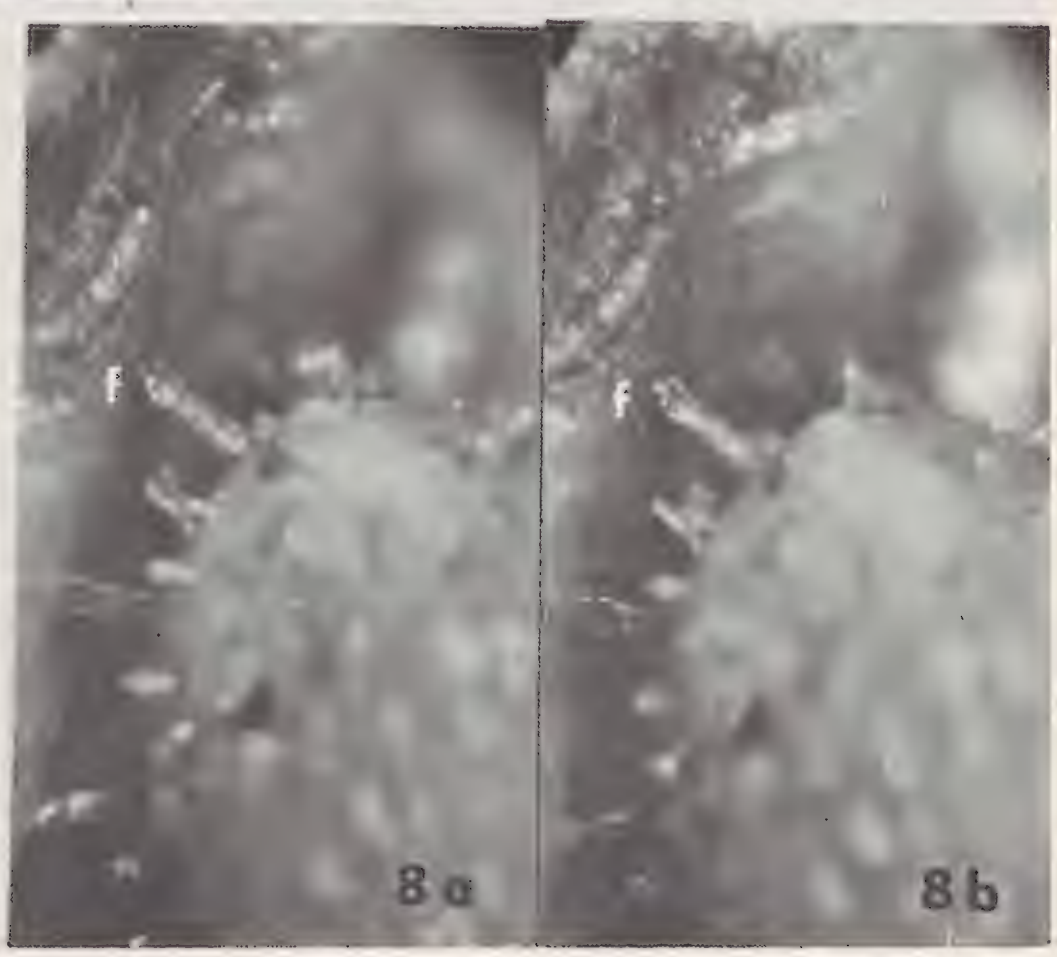




PLATE 2

markedly depressed (pl. 8, fig. 6). In most specimens the final intercameral suture is well above the base of the test (pl. 8, figs. 2,6), but in some 4-chambered forms it approaches the base more closely (pl. 9, figs. 1,2). The intercameral septa are rarely preserved in either juvenile or mature specimens, a phenomenon also observed in several fossil species of "*Globulina*" (Le Calvez, 1950). They apparently have been resorbed during growth creating a monothalamous condition (pl. 5, fig. 2). Varying degrees of resorption have been recorded in living genera, including *Elphidium* (Jepps, 1956), *Patellina, Discorbis,* and *Cymbalopora* (Myers, 1943), and *Cibicides* (Nyholm, 1961).

*Aperture*

The aperture is situated at the distal end of the final chamber, which is generally less spinose than the rest of the test surface (pl. 2, fig. 6). It consists of a system of hollow cylindrical tubules that radiate outward from a common vestibule at the distal end of the final chamber lumen (pl. 5; figs. 3,4; pl. 6, figs. 1-9; pl. 7, figs. 6-9; pl. 9, fig. 7). These tubules are widest at the inner ends, narrowing as they extend outward and upward toward the surface (pl. 5, figs. 3,4; pl. 9, fig. 7). On the outer test surface they open as small circular foramina, often in the center of low conical elevations (pl. 7, figs. 2-5). These elevations are part of a protruding cylindrical neck or low hummocky mass of thick, non-perforate calcite (pl. 2, fig. 1; pl. 5, fig. 3; pl. 7, figs. 2,4; pl. 8, figs. 1-10). The basic pattern is a symmetrical radiation of tubules (pl. 6, figs. 1-9), but they may be irregularly placed (pl. 7, fig. 1; pl. 9, fig. 8), and some may extend subparallel to the long axis of the test.

The radiate tubular apertural system of *Vasiglobulina* appears to have developed in the Late Cretaceous or early Paleogene Period from the polymorphinid system of radiating slits, which arose in the Triassic Period (Loeblich and Tappan, 1964). The oldest specimen of *Vasiglobulina* examined by the writer is of upper Eocene age. Some species probably referable to the genus have been reported from Eocene rocks by Cushman and Ozawa (1930; *V. verrucosa*), Bandy (1949; *V. alabamensis* ?), and Deboo (1965; *V. alabamensis* ?). *Globulina lacrima ericia* of Cushman and Ozawa (1930) may be a Cretaceous representative.

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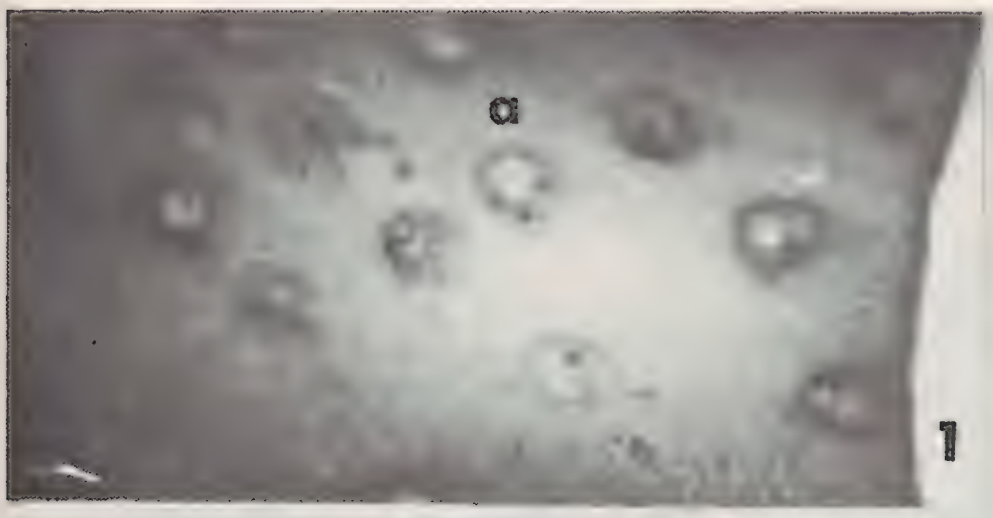
PLATE 3

*Vasiglobulina alabamensis* (Cushman and McGlamery). All specimens from the Chickasawhay Formation at Taylor Mill Creek, near Waynesboro, Mississippi. Figures 1-5 all same specimen.

Figures

1 Interior surface of test wall; focus on surface. Note absence of structure in spines; glycerine mount, transmitted light. X 200
2 Interior surface of test wall; focus below surface. Note absence of structure in spines. X 200
3 Interior surface of test wall; focus on surface. Note continuity of pore pattern across spine base "a." X 860
4 Interior surface of test wall under crossed nicols. Note spines do not extinguish with the rest of test wall. X 860
5 Interior wall of test fragment under crossed nicols. Note dark extinction figure produced by radially arranged calcite crystals; bright spots are spine bases. X 100
6 Mollusc fragment. Dark angular spots are spine stubs of *Vasiglobulina alabamensis.* X 180
7 Hypotype B viewed from underside of mollusc fragment, showing spines (dark angular spots) completely penetrating the mollusc shell. X 90
8 Enlargement of figure 7. Note angularity of spines in transverse section. X 180



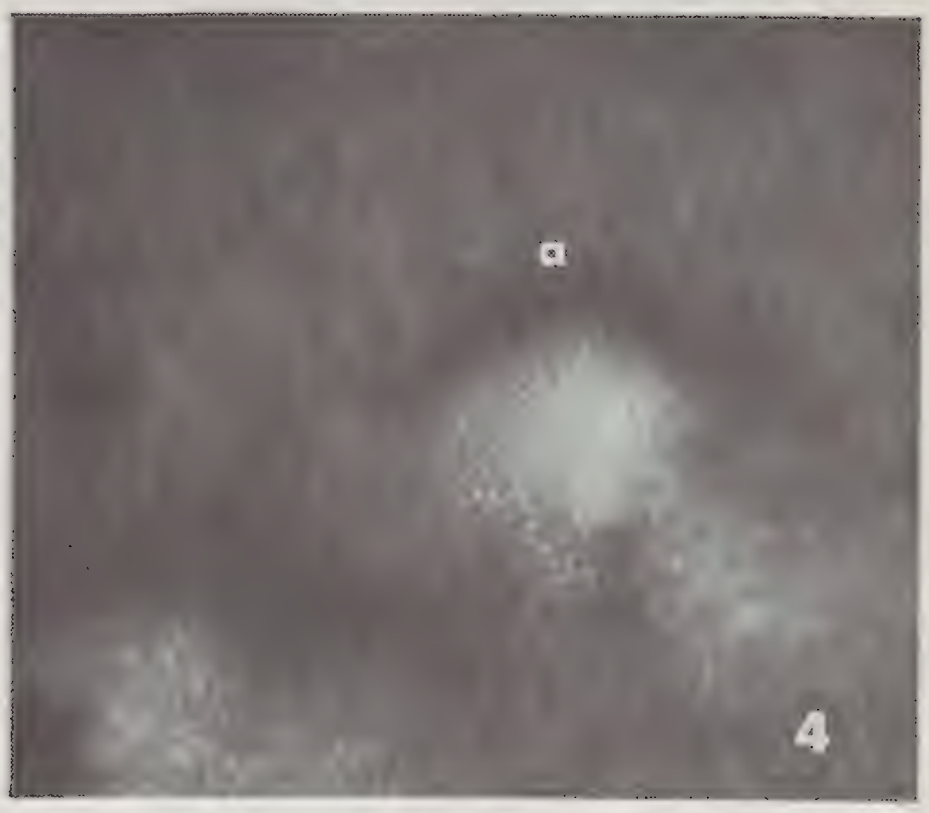


PLATE 3

The polymorphinid aperture consists of a distal cavity in the lumen of the final chamber, from which elongate radiating slits extend to the test surface and open between calcareous plates. These plates generally converge at the distal end of the final chamber, where they either join or leave a narrow apical gap. Transition to the vasiglobuline type of aperture can be accomplished by adding a calcite plug that fills most of the apertural cavity, blocking the distal portions of the slits and, thus, leaving only hollow tubules branching off a central vestibule (text fig. 2). Le Calvez (1950) describes a cylindrical canal in the neck of *Globulina gravida* (Terquem), which may represent a depature toward the vasiglobuline condition.

## V. Morphological Variation

The Polymorphinidae are notorious for the wide range of morphological variation at the species level. The plasticity of test shape and the frequent occurrence of fistulose apertural growths are the most common manifestations of this flexibility. *Vasiglobulina alabamensis* is no exception to this pattern; it displays numerous variations in test shape, spinosity, and apertual characteristics.

### *Test Shape*

Most 4-chambered specimens are pyriform, with rounded initial ends and tapered apertural ends (pl. 8, figs. 4,10). They are generally longer than broad, but in some, breadth may almost equal length (pl. 9, fig. 2). In longitudinal view, most are bilaterally symmetrical (pl. 8, figs. 4,7,10), but some are asymmetrical, protruding markedly at one side (pl. 9, figs. 1,2). A few specimens are sharply tapered initially and broadly rounded aperturally (pl. 8, fig. 5); infrequently, both ends taper (pl. 9, fig. 5).

### *Spinosity*

In general, the spines are arranged on the surface of the test with no clear relationship to one another except that the apertural region is relatively smooth. Individual specimens, however, may display lineation of some spines (pl. 8, fig. 2; pl. 9, fig. 2), and in some, even the apertural region is spinose (pl. 7, fig. 8; pl. 9, fig. 5). Density of spines varies considerably among speci-

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## Plate 4

*Vasiglobulina alabamensis* (Cushman and McGlamery)

Figures

1 Hypotype D, U.S.N.M. No. 687809; topotype from the Chickasawhay Formation near Millry, Alabama, showing well preserved spines; lettered spines are enlarged in figures 2-10; note apparent lack of internal structure. X 90

2,3 Spine "a." Note tapering and irregularly broken tip. 2, X 430; 3, X 860

4 Spine "b." X 430

5,6 Spine "c." Note hourglass shape and irregularly broken tip. 5, X 430; 6, X 860

7 Spine "c" under crossed nicols; note broad color bands denoted by horizontal white lines. X 860

8 Spine "d." X 430

9,10 Spine "e." Note distal thickening and flatly broken tip. 9, X 430; 10, X 860

11 Hypotype from the Red Bluff Clay at Hiwannee, Mississippi. Note distal thickening and digitation and the alignment of the flat broken surfaces indicating site of previous attachment; spine "f" enlarged in figure 12. X 430

12 Enlargement of spine "f," figure 11. X 860

13,14 Spines of specimen from the Chickasawhay Formation at Taylor Mill Creek, near Waynesboro, Mississippi; transverse sections under crossed nicols. Note absence of extinction, angularity of outline, lack of internal structure, and peripheral indentations resulting from longitudinal grooves on exterior of spines. X 860

PLATE 4

mens and on individuals (pl. 8, figs. 1-10); they may be arranged in thick patches (pl. 8, fig. 6), or widely scattered (pl. 8, figs. 5,8). The shape in transverse section varies from circular to ovate to angular (pl. 3, figs. 1-8; pl. 4, figs. 13,14). Most project perpendicularly to the outer test surface (pl. 4, figs. 9,11), but others may project at different angles (pl. 4, fig. 4). Spine diameter is variable; one specimen may have predominantly thick spines (pl. 8, fig. 2), and another of similar size and number of chambers may have predominantly thin ones (pl. 8, fig. 4). Spines of various diameters are often present on a single specimen (pl. 8, fig. 3). Some spines are hourglass-shaped in longitudinal outline (pl. 2, fig. 2; pl. 4, fig. 6), but most taper to their preserved extremities (pl. 4, figs. 2,4). Some display longitudinal grooves (text fig. 1A,B) or digitation (pl. 4, figs. 11,12) at their distal extremities. Some spines display longitudinal grooves that can be seen only at high magnification (text fig. 1A,B). The presence of these grooves is reflected by peripheral indentations of the spines when viewed in transverse section (pl. 4, figs. 13,14).

*Aperture*

In observed specimens, the number of tubules constituting the aperture varies from a minimum of 7 (pl. 6, figs. 1-7) to a maximum of 19 (pl. 9, fig. 8). These tubules generally radiate subsymmetrically (pl. 6, figs. 1-7), but may also be conspicuously asymmetrical (pl. 7, fig. 1; pl. 9, fig. 8). The height and size of the exterior apertural mound is variable. It may extend as a distinct neck-like protuberance (pl. 8, fig. 1; pl. 9, fig. 7) or may be nearly flush with the rounded test surface (pl. 8, fig. 6). It may be symmetrically lobate, with each pore opening in the center of a conical elevation (pl. 6, fig. 5; pl. 7, figs 2-5), or may be a thickened irregular mass of nodose and spinose calcite (pl. 9, fig. 5).

## VI. Functional Morphology

*Shape of Test*

The ovoid or pyriform shape of the test of *Vasiglobulina alabamensis* suggests orientation of the long axis parallel to the sea bottom and to the dominant current direction in order to provide a more stable hydrodynamic configuration. This, together with

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## Plate 5

*Vasiglobulina alabamensis* (Cushman and McGlamery). All specimens from the Chickasawhay Formation at Taylor Mill Creek, near Waynesboro, Mississippi.

Figure

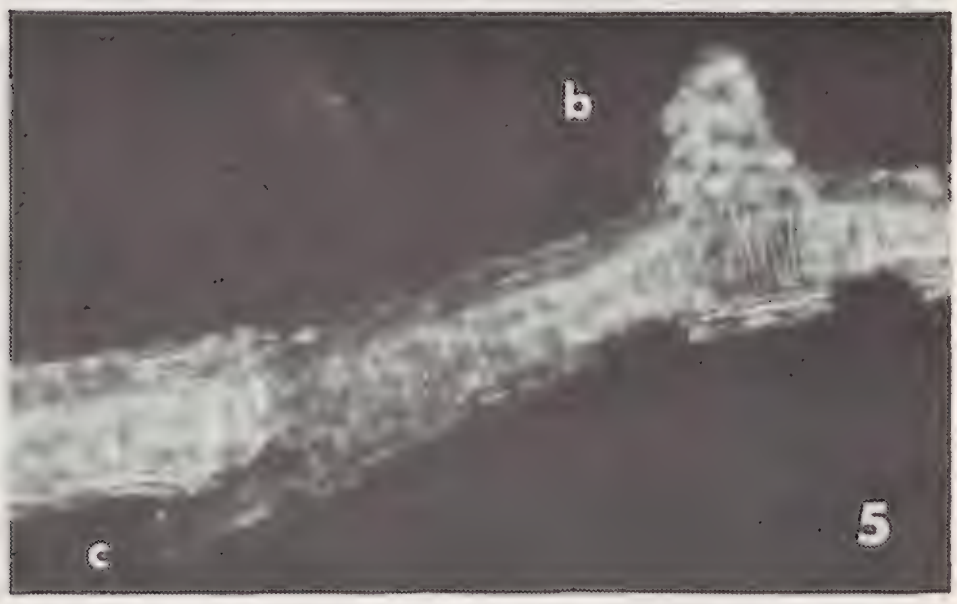
1 Attached hypotype A showing spines penetrating edge of mollusc fragment; black line indicates interior surface of mollusc. Note slight thickening of spine "a" as it passes into the shell. X 200

2 Longitudinal section of specimen under crossed nicols. "a" = apertural region; "b" = spine enlarged in figures 5-7; "c" = remnants of internal septum separating final two chambers. X 100

3,4 Apertural section of figure 2. Upper ends of hollow tubules "t" extend below plane of section, narrowing upward; note absence of perforate wall structure in apertural mound. Perforations can be seen in wall at lower left of figure 3. Figure 3, X 430; 4, X 860

5,6 Portion of wall of figure 2 showing spine structure completely penetrating lamellae of juvenile test wall; note septal remnant "c." 5, X 430, crossed nicols; 6, X 430, plane polarized light.

7 Spine "b" of figures 2,5,6. Note spine structure present through entire wall; perforate wall structure absent in spine (apparent pores in lower portion of spine are below the plane of section); minute pores of wall curve outward away from spine base. X 860



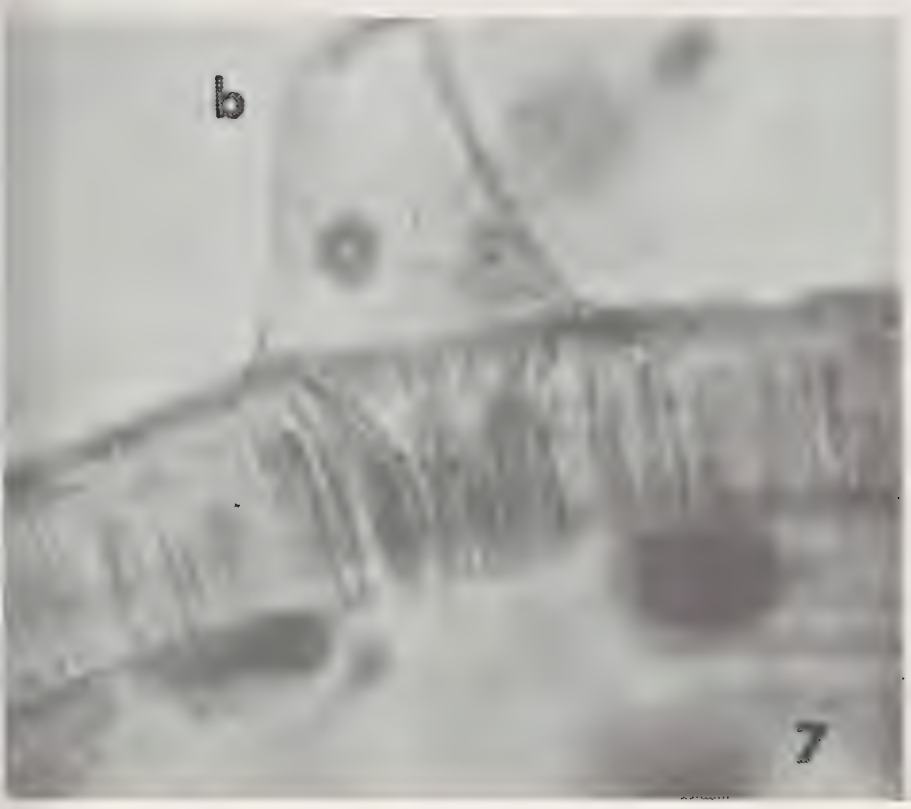
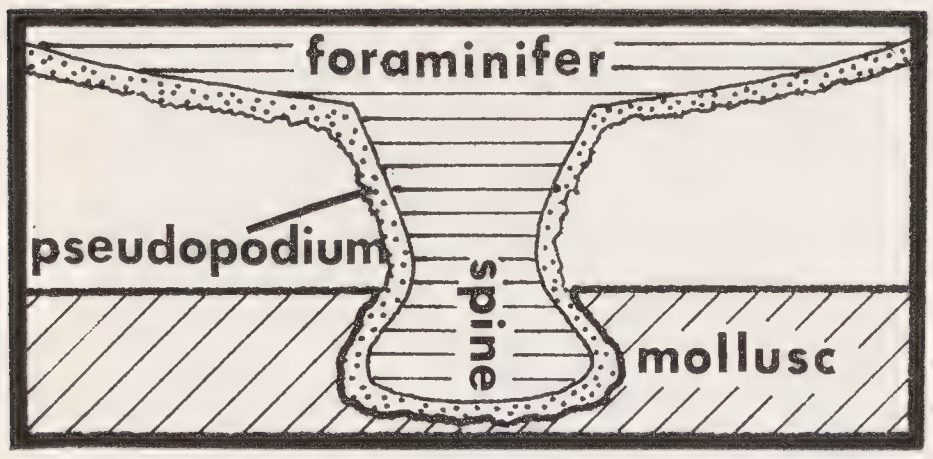



PLATE 5




TEXT FIGURE 3

Exaggerated diagrammatic section showing penetration of mollusc fragment by pseudopodium and hourglass-shaped spine. Thickened distal end prevents loss of attachment.

the need for such firm attachment, indicates that the species is part of the epifauna, not the infauna.

*Size of Aperture*

Narrowing of the apertural openings from elongated slits, as in many other polymorphinids, to the minute, circular foramina of *Vasiglobulina* may be a response analagous to the development of a tooth structure in some miliolids and buliminids. Arnold (1964) has suggested several possible advantages that may be derived from such constricted apertural openings. Some of his suggestions are applicable to *Vasiglobulina.*

1) The constriction may serve as a check valve to prevent premature extrusion of nucleated protoplasm; prevent entry of large predators, food particles, or debris; or, prevent proximal migration of large vacuoles.

2) It may facilitate segmentation of multinucleate protoplasm during schizogony.

3) It may change the velocity of protoplasmic flow and complicate circulation, lengthening the exposure of food particles to extrathalamous digestion. Pseudopodial digestion of larger food particles may logically be expected in *Vasiglobulina,* since the apertural openings are small relative to such food material as larger diatoms. Extrathalamous digestion has been reported in living forms such as *Elphidium* (Jepps, 1942).

*Spines*

The attaching spines are permanently wedged within the dissolution cavities in the mollusc fragments by varying degrees of distal thickening (text fig. 1B). A conspicuous hourglass shape is produced in those spines that thicken most (text fig. 3; pl. 2, fig. 2), but this shape is not apparent in those spines that thicken only slightly (pl. 2, fig. 3).

The non-attaching spines may serve to brace the waving pseudopodia against cur-

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PLATE 6

*Vasiglobulina alabamensis* (Cushman and McGlamery) from the Chickasawhay Formation at Taylor Mill Creek, near Waynesboro, Mississippi. All figures are of the same specimen; transmitted light, glycerin mount.

Figure

1,2 Interior view of aperture showing tubules radiating downward below plane of paper; small dark spots are spine bases; glycerin forms dark ring around radiating tubules. 1, X 200; 2, X 420

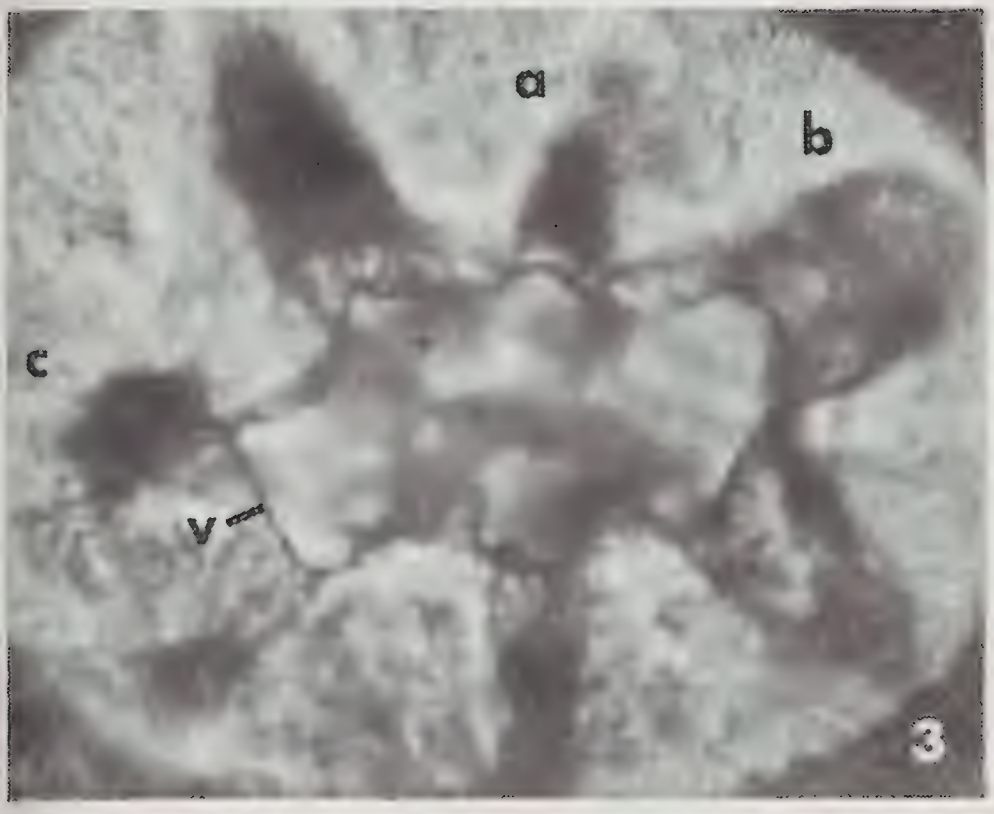
3 Interior view of aperture; focus on interior rim of vestibule into which all tubules open interiorly; tubules "a" and "b" are shown in lower focus in figure 4. "v" = edge of vestibule (irregular ovate outline). X 860

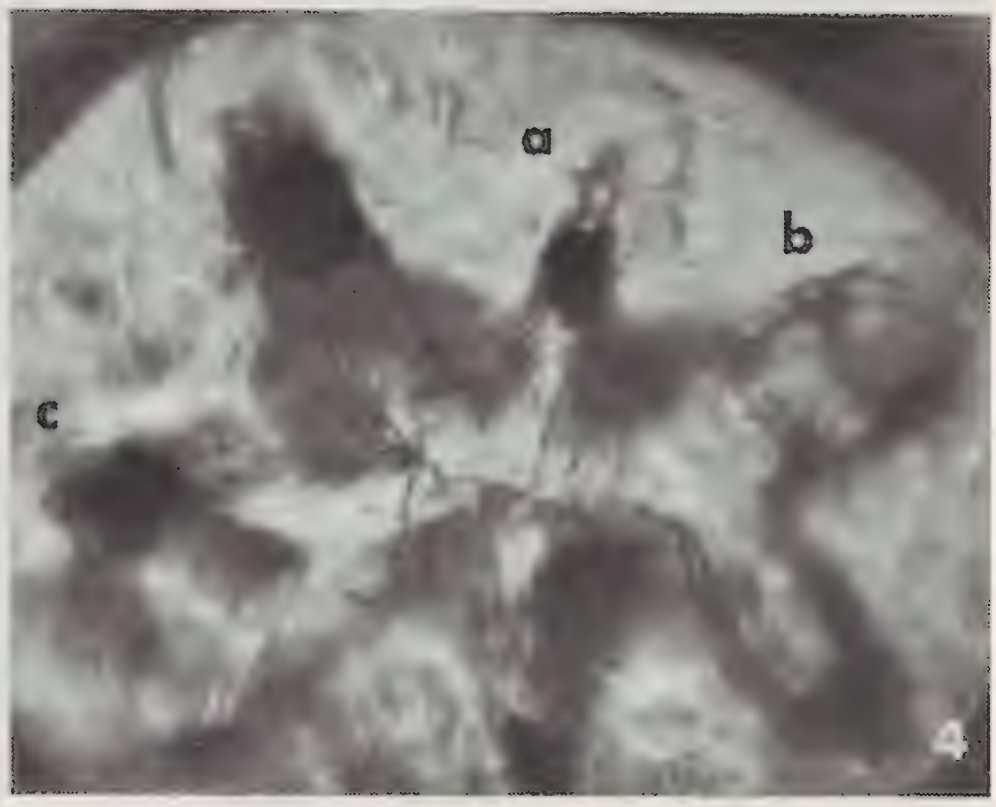
4 Interior view of aperture; focus lower than in figure 3 (below rim of vestibule and closer to exterior surface below plane of paper; note narrowing of tubules "a" and "b" as they approach exterior surface. X 860

5-7 Exterior apertural view; note reversed position of tubules as indicated by "b" and "c"; tubule "c" shows normal configuration of external foramina; tip of tubule "b" is broken, resulting in enlarged exterior foramen; dark material in tubules is green food coloring. Note lobate outline of apertural mound in 5 and 6. 5, X 200; 6, X 420; 7, X 860

8 Detail of tubule "b" showing broken tip. X 860

9 Detail of tubule "c" showing normal tip. X 860



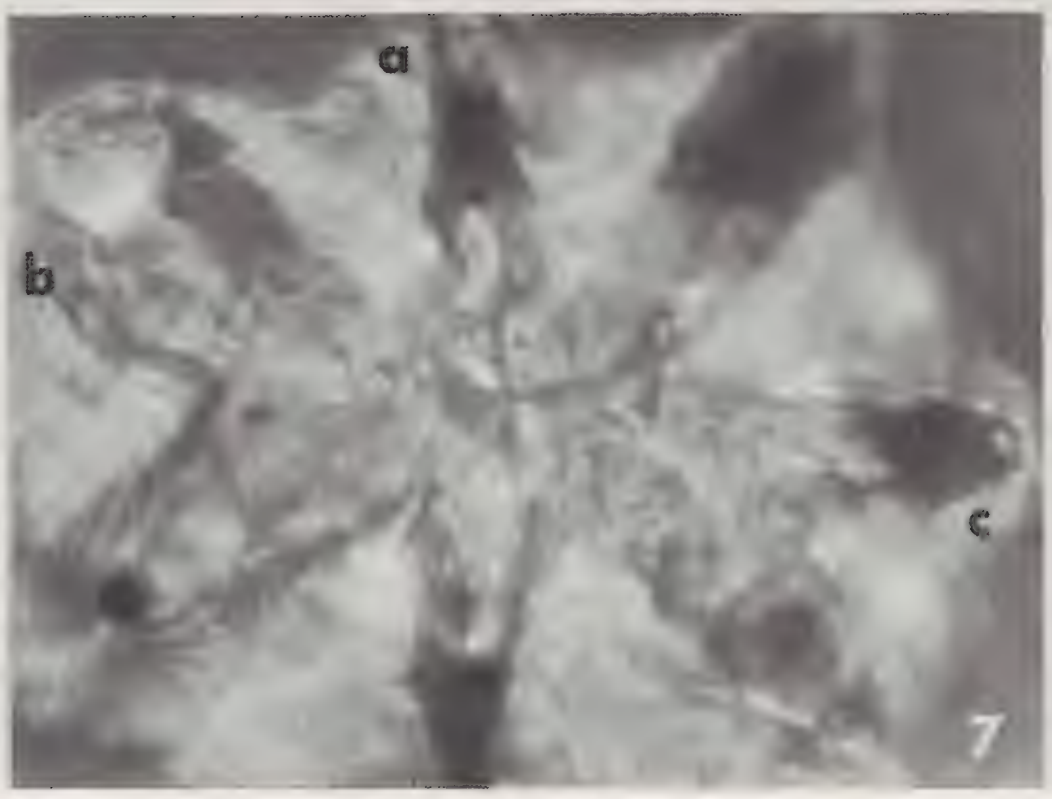


PLATE 6

rents in the inferred epifaunal environment. This would increase efficiency in active food gathering by enhancing their directed motion toward food particles. They may also augment passive food capture by serving as a framework for the outstretched network of pseudopodial strands.

*Attached Condition*

Arnold (1964) has described the retraction of pseudopodia of the foraminifer *Spiroloculina hyalina* in response to prolonged unfavorable conditions in its environment. Since this species adheres to to the substratum only by means of pseudopodia, the consequent loss of attachment or means of active locomotion leaves it at the mercy of external forces of displacement, even though it is able to remain practically dormant for long periods of time. Under similar circumstances, the permanent attachment of *Vasiglobulina alabamensis* would enable it to remain stationary even after withdrawing its pseudopodia, thus being protected from dislodgement until favorable conditions were restored. A similar advantage is gained by such attachment if pseudopodia are withdrawn after periods of feeding or during reproduction, as in *Allogromia laticollaris* (Arnold, 1953).

*Time of Attachment*

*Vasiglobulina alabamensis* attaches to the concave internal surface of mollusc fragments as well as to the convex outer surface. In specimens attached to the inner side, there is no mounding or irregular lamination of calcite to suggest interruption of normal nacre deposition by the mantle of the mollusc. Such interruption would be expected if attachment were accomplished while the mollusc lived (see Todd, 1965; Meglitsch, 1967). It is improbable that such a spinose form, which presumably would be highly irritating to its host, could survive within the shell of the living mollusc.

The time of attachment during the life cycle of the foraminifer can not be de-

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PLATE 7

*Vasiglobulina alabamensis* (Cushman and McGlamery) from the Chickasawhay Formation at Taylor Mill Creek, near Waynesboro, Mississippi; all except figure 2 taken with transmitted light.

Figure

1 Interior apertural view showing asymmetry of tubular arrangement and large number of tubules; compare with specimen on plate 6; dark circles are air bubbles trapped in tubules (glycerin mount). X 420

2 Hypotype E, U.S.N.M. No. 687810. Lateral view showing apertural end of longitudinal axis tilted toward viewer (top of photograph); note symmetrical lobation of apertural mound. Reflected light. X 90

3 View identical to figure 2; transmitted light; exterior opening of one tubule is barely visible at "a." X 90

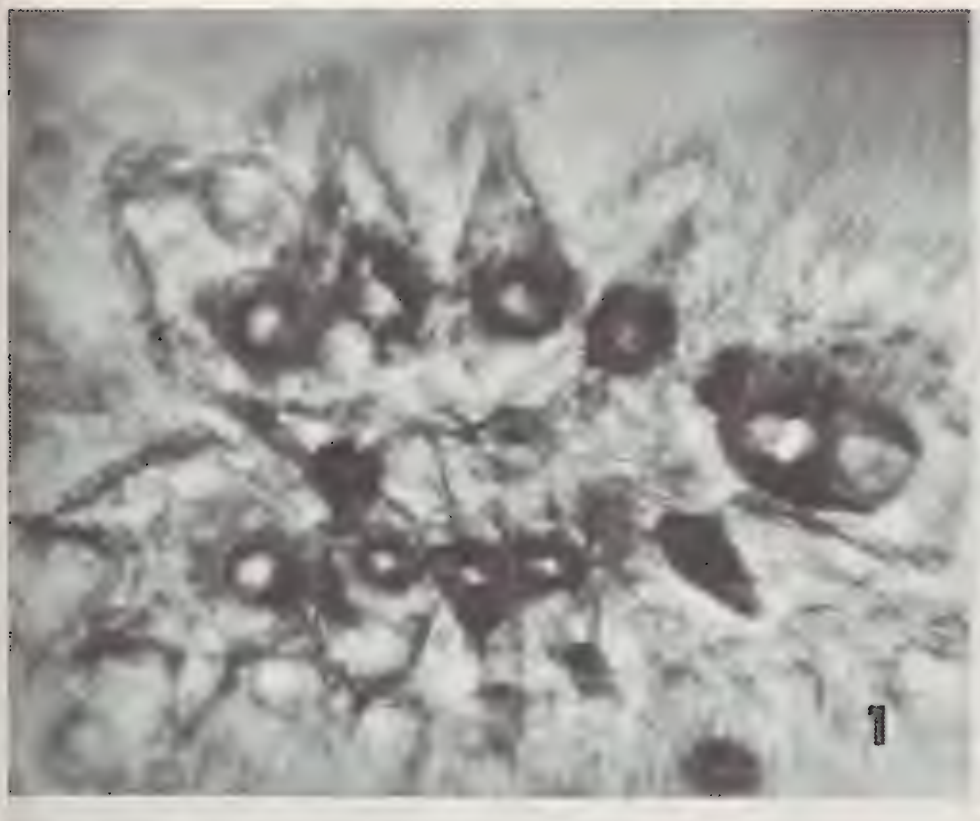
4,5 Lateral view of apertural mound; same specimen as figures 2,3; note conical elevations containing exterior foramina of tubules "a," "b," and "c"; note circularity of foramen "a." 4, X 420; 5, X 860

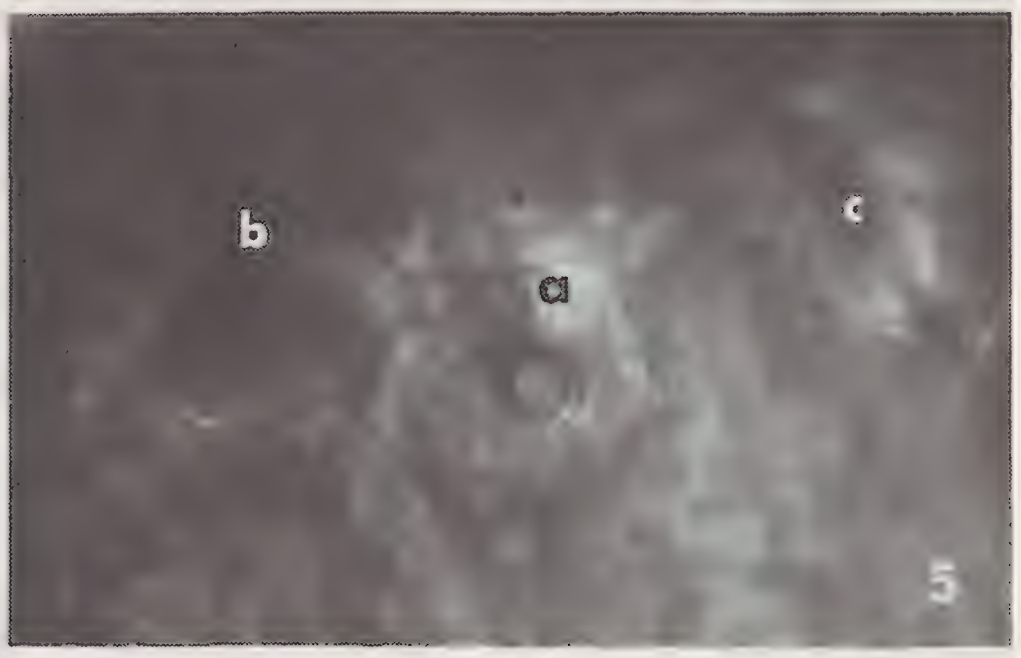
6 Longitudinal section through one side of apertural mound; section does not contain plane of the long axis, therefore, tubules appear as five circular openings in slightly oblique transverse section. X 100

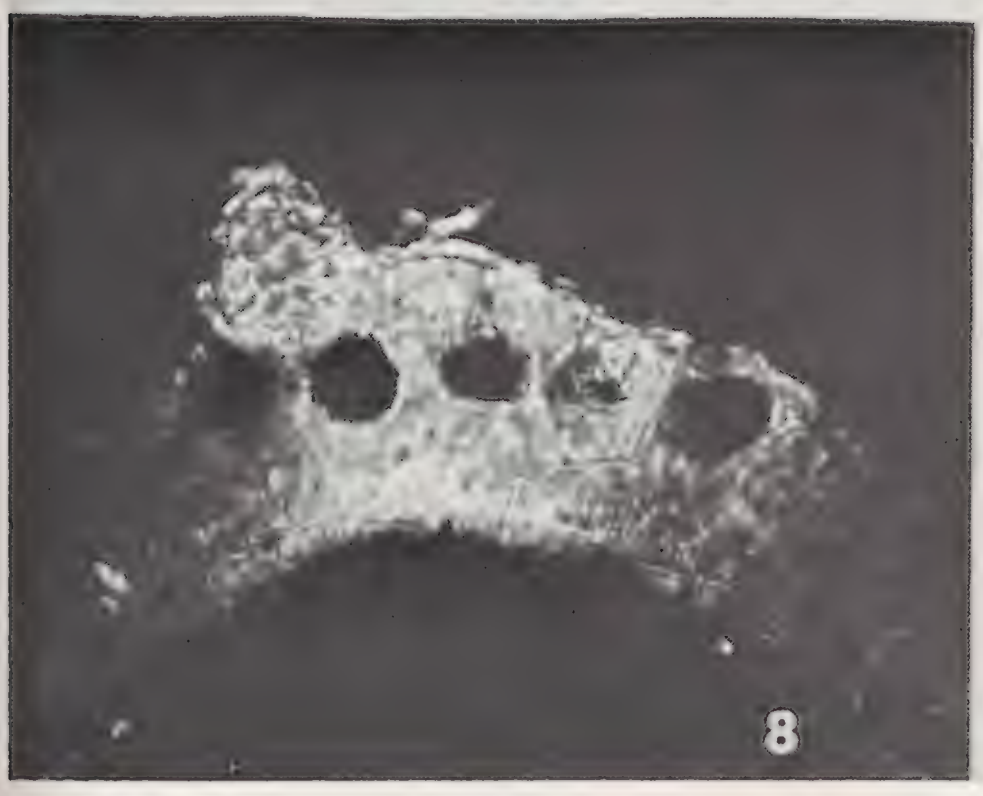
7 Longitudinal section as above; apertural mound; plane polarized light; note spine projecting from apertural mound; pore structure along interior surface of apertural mound is due to thickness of section, which preserves a portion of the curved wall of final chamber; three openings are filled with green food coloring. X 430

8 Longitudinal section as in figure 7; crossed nicols; one arm of black cross extinction figure seen on either side of apertural mound. X 430

9 Longitudinal section of apertural mound; enlargement of figure 7. X 645







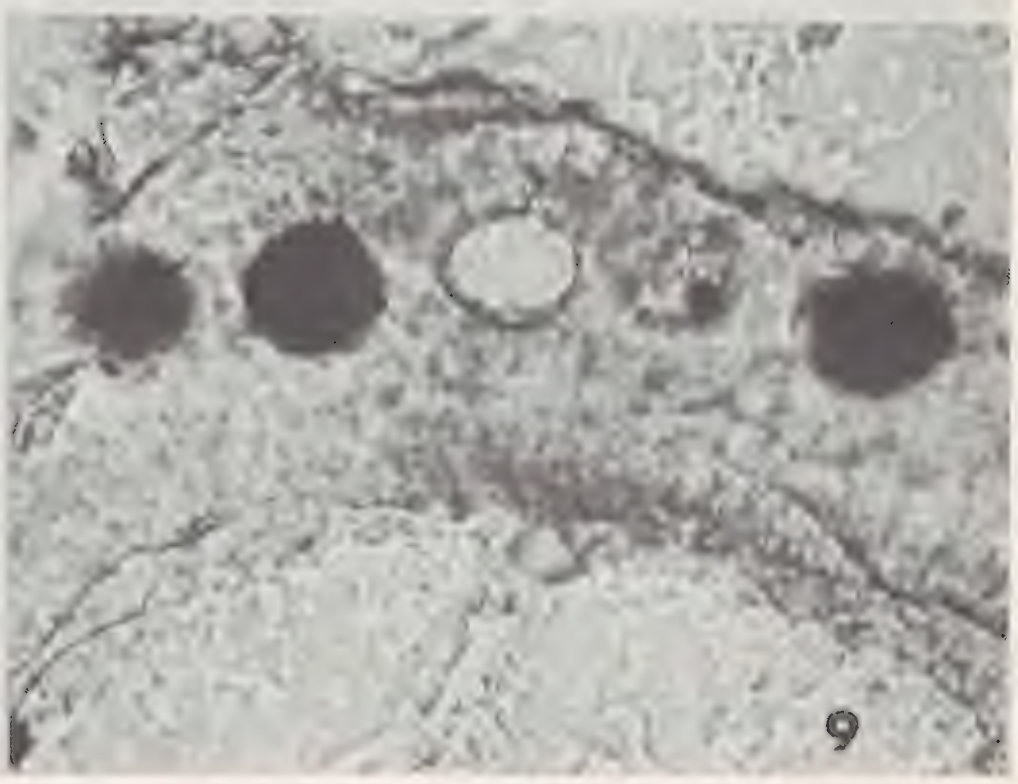




PLATE 7

termined from present data. No juveniles were observed either attached or bearing hourglass-shaped spines. The penetration of the juvenile layers of the test by some spines (pl. 5, figs. 5-7) indicates that *Vasiglobulina alabamensis* became spinose early in ontogeny, but this does not necessarily imply early attachment.

*Dissolution of Exotic Calcite*

It is conceivable that *Vasiglobulina alabamensis* may use the ability to dissolve exotic calcite for purposes other than attachment. Such a capacity would permit it to prey upon other small organisms that possess calcareous hard parts, such as foraminifers and ostracodes.

## VII. Paleoecological Implications

*Vasiglobulina alabamensis* attached itself to molluscan fragments for anchorage in a shallow, moderate energy marine environment. Poag (1966) has suggested that Paynes Hammock beds in which this species was recorded were deposited in water depths of 40-120 feet, with bottom salinity of 34-36.5‰, and bottom temperature of 20-27° C. The Chickasawhay foraminiferal fauna is similar to the Paynes Hammock, requiring similar paleoecological conditions. The association of *Vasiglobulina alabamensis* with such attached forms or *Cibicides lobatulus, Webbinella fimbriata, Cycloloculina miocenica,* and *Planorbulinella larvata* (Poag, 1966) implies water turbulence. Attachment by dissolution of molluscan calcite would limit the selectivity of substrata for the species if attachment were obligatory to survival, as it could become viable only in the presence of sufficient molluscan fragments.

## VIII. Pseudopodial Functions

The pseudopodia of foraminifera are elongate, granuloreticulose extensions of protoplasm which perform with marvelous versatility a wide array of functions as vividly described by many authors, including Lister (1903), Heron-Allen (1915), Cushman (1920), Myers (1943), Jepps (1956), Nyholm (1961), Arnold (1964), Hedley (1964), Loeblich and Tappan (1964), Boltovskoy (1965), and Angell (1967). The most frequently cited pseudopodial functions are those concerned with the capture, ingestion, and digestion of food, the con-

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## Plate 8

*Vasiglobulina alabamensis* (Cushman and McGlamery); all specimens from the same sample of the Chickasawhay Formation at Taylor Mill Creek, near Waynesboro, Mississippi. Note morphological variation, especially in prominence of apertural mound; size and shape of test; length, diameter, density, and location of spines. Apertures are toward top of page; all X 90.

Figure

1 Hypotype F, U.S.N.M. No. 687811; 4 chambers; note neck-like extension of apertural mound.
2 Hypotype G, U.S.N.M. No. 687812; 4 chambers; note alignment of spines and their large diameter compared to figure 4.
3 Hypotype H, U.S.N.M. No. 687813; 4 chambers.
4 Hypotype I, U.S.N.M. No. 687814; 4 chambers; note symmetrical pyriform shape and small diameter of spines.
5 Hypotype J, U.S.N.M. No. 687815; 4 chambers; note acuminate initial end and broadly rounded apertural end; spines are widely scattered.
6 Hypotype K, U.S.N.M. No. 687816; 5 chambers; note thick patches of spines; aperture is nearly flush with surface of test.
7 Hypotype L, U.S.N.M. No. 687817; 5 chambers; note bilateral symmetry.
8 Hypotype M, U.S.N.M. No. 687818; 5 chambers; note widely scattered spines.
9 Hypotype N, U.S.N.M. No. 687819; 4 chambers.
10 Hypotype O, U.S.N.M. No. 687820; 4 chambers; note symmetrical pyriform shape.

PLATE 8

struction of organic and inorganic layers of the test wall, the formation of protective cysts during chamber addition and reproduction, locomotion, and the temporary or semipermanent attachment to the substratum.

In most forms, pseudopodia extend from the primary aperture in a spreading reticulose mesh of slender tendrils. A thin layer of cytoplasm may also extend over the exterior of the test. In highly spinose planktonic forms, the pseudopodia extend along and between the radiating spines, the protoplasmic granules apparently streaming up and down the spine surfaces.

Temporary attachment by pseudopodia in benthonic species is generally accomplished by spreading the myriad extensions into the soft substratum. It may be achieved by relatively rigid pseudopodia, allowing erect posture of the test, as in *Hippocrepina*, or by more fragile pseudopodia which extend horizontally outward from the test, as in *Phainogullmia* (Nyholm, 1957).

Based on its peculiar mode of attachment, the writer infers that the pseudopodia of *Vasiglobulina alabamensis* enveloped the spines as in some planktonic species. In order to attach, they created narrow cavities in the molluscan fragments by dissolving the molluscan conchiolin and calcite. The latter phenomenon has been previously described only in *Rosalina carnivora* (Todd, 1965). It is logical to assume that this dissolved calcite was then redeposited as penetrating foraminiferal spines, to provide the most efficacious attachment known in the Foraminiferida. *Vasiglobulina alabamensis*

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## Plate 9

*Vasiglobulina alabamensis* (Cushman and McGlamery); apertural ends are at top of page.

Figure

1 Hypotype P, U.S.N.M. No. 687821; from the Chickasawhay Formation at Taylor Mill Creek, near Waynesboro, Mississippi; 4 chambers. Note widely spaced spines and broadly rounded base which bulges outward at lower right. X 90

2 Hypotype Q, U.S.N.M. No. 687822; from the Chickasawhay Formation at Taylor Mill Creek, near Waynesboro, Mississippi; 4 chambers. Note longitudinal lineation of spines and broad flattened base which bulges outward at lower right; final intercameral suture extends almost to base of test. X 90

3 Hypotype R, U.S.N.M. No. 687823; from the Mint Spring Marl Member of the Marianna Limestone at its type locality near Vicksburg, Mississippi; 4 chambers. Note symmetrical pyriform outline and even distribution of spines. X 90

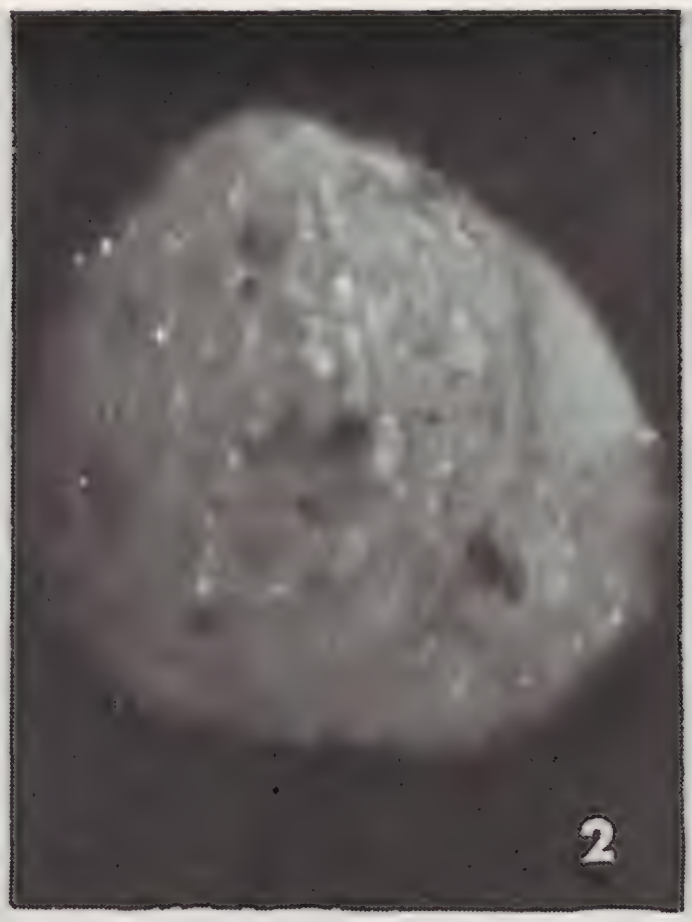
4 Hypotype S, U.S.N.M. No. 687824; attached specimen from the Red Bluff Clay at Hiwannee, Mississippi; Note angle of attachment relative to long axis of test. X 90

5 Hypotype T, U.S.N.M. No. 687825; from the Paynes Hammock Formation on the Chickasawhay River, near Waynesboro, Mississippi; number of chambers not discernible. Note thick clusters of spines, especially around apertural mound, and large size of test; both ends of test are acuminate. X 52.5

6 Stereopair of portion of specimen from the Red Bluff Clay at Hiwannee, Mississippi. Spines fuse into amorphous mass; one flares into a hollow, horn shaped structure. X 180

7 Apertural mound of entire specimen from the Chickasawhay Formation at Taylor Mill Creek, near Waynesboro, Mississippi; lateral view. Note outline of radiating hollow tubules ("t") within mound; focus below surface of mound; transmitted light, glycerin mount. X 430

8 Exterior apertural view of specimen from the Chickasawhay Formation at Taylor Mill Creek, near Waynesboro, Mississippi. Note large number (19) of asymmetrically arranged tubules; focus near exterior surface; reflected light. X 200



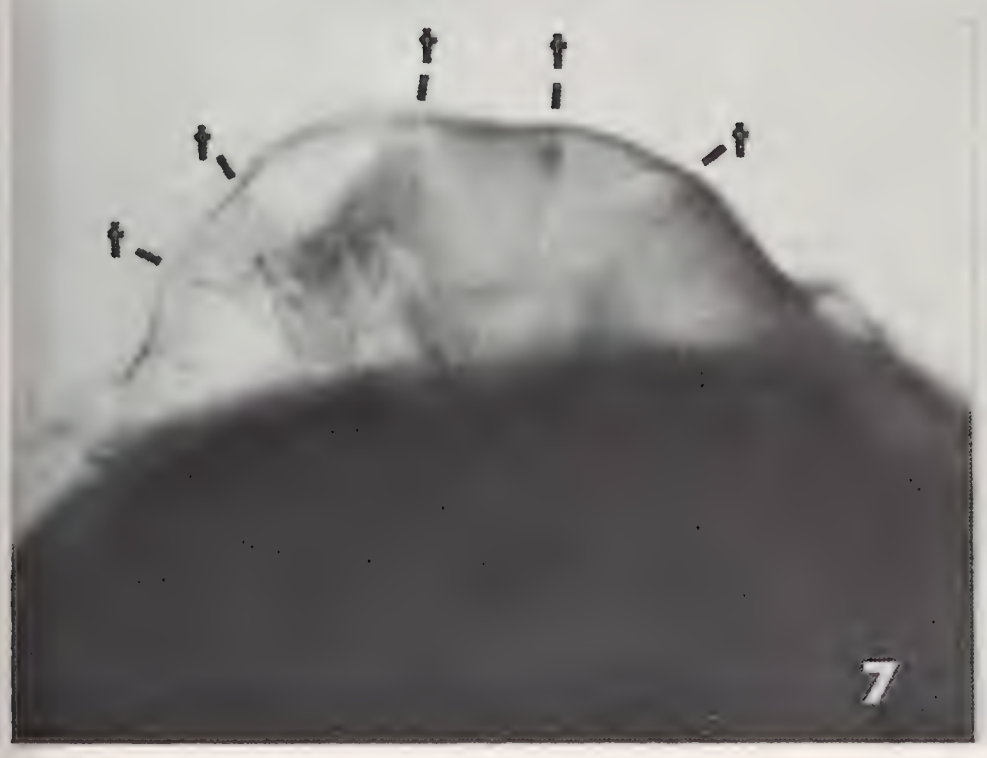


PLATE 9

provides new insight into some little known functions of foraminiferal pseudopodia.

## IX. Geologic and Geographic Distribution

### *Gulf Coast*

*Vasiglobulina alabamensis* was first reported in the Gulf Coast (as *Polymorphina spinosa* d'Orbigny) from the Mint Spring Marl Member of the Marianna Limestone at Mint Spring Bayou, near Vicksburg, Mississippi, and from the Glendon Limestone and calcareous marl members of the Byram Formation from various Mississippi and Alabama localities (Cushman, 1922b). Cushman referred to " . . . numerous short, projecting spines which seem to be hollow where broken." Howe (1934) reported what is apparently the same species as *Globulina spinosa* from the Chickasawhay Formation at Taylor Mill Creek, near Waynesboro, Mississippi. In 1938, Cushman and McGlamery recorded a specimen provisionally as *Globulina inaequalis* Reuss var. *caribaea* d'Orbigny from the Chickasawhay Formation at Choctaw Bluff, Alabama. They noted " . . . an irregularly spinose specimen . . . whose spinose projections are very irregularly scattered, much more so than in Recent forms of the species." From these remarks and their illustrations, the writer infers that this is *Vasiglobulina alabamensis.* The taxon *Globulina alabamensis* was erected the following year (Cushman and McGlamery, 1939) based on a holotype and three paratypes from the Chickasawhay Formation near Millry, Alabama (see pl. 1, figs. 1-9). It was originally described as follows:

> "Test slightly longer than broad, both ends broadly rounded, periphery broadly rounded, thickness slightly less than the breadth; chambers few, only slightly inflated, increasing rapidly in size as added, last-formed chamber making up at least half the surface in the adult; sutures distinct, sigmoid in the adult, little if at all depressed, very slightly limbate; wall ornamented with numerous short spines, rather evenly scattered over the whole surface; aperture terminal, radiate."

It has subsequently been recorded (Cushman and McGlamery, 1942) from the Chickasawhay Formation near Millry, Alabama, and apparently assigned to two different species (*Globulina alabamensis,* pl. 5, figs. 1-4; and *Globulina inaequalis cari-*

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## Plate 10

Figure

1 *Vasiglobulina tuberculata* (d'Orbigny); topotype from the *Amphistegina* Marl near Vienna, Austria. Note thick bluntly broken spines; a large one extends from the apertural mound. X 52.5
2 *Vasiglobulina punctata* (d'Orbigny); specimen from the Coralline Crag of Suffolk, England; note finely hispid exterior surface. X 90
3 *Vasiglobulina striata* (Egger); topotype from the Miocene near Ortenburg, L. Bavaria. Note weakly spinose costae. X 90
4 *Vasiglobulina tuberculata* (d'Orbigny); apertural view of figure 1. X 100
5 *Vasiglobulina punctata* (d'Orbigny); apertural view of figure 2. X 210
6 *Vasiglobulina striata* (Egger); apertural view of figure 3. X 210
7 "*Globulina*" sp.; smooth specimen from Piacenza, Italy. X 52.5
8 *Vasiglobulina* sp.; finely hispid specimen from Piacenza, Italy. X 52.5
9 "*Globulina*" sp.; smooth specimen from the Chickasawhay Formation near Millry, Alabama. X 52.5
10 "*Globulina*" sp.; apertural view of figure 7. X 210
11 *Vasiglobulina* sp.; apertural view of figure 8. X 210
12 "*Globulina*" sp.; apertural view of figure 9. X 210
13 *Vasiglobulina variata* (Jones, Parker, and Brady); topotype from the Coralline Crag of Suffolk, England; note sparse thick short spines. X 90
14 *Vasiglobulina tuberculata?* (d'Orbigny); specimen from the Pliocene near Piacenza, Italy; note thick rounded spine bases on exterior surface. X 90

PLATE 10

*baea,* pl. 4, fig. 36; not figs. 34,35). One specimen of the latter was reported attached to a mollusc fragment. It has been reported from the Byram Marl at Byram, Mississippi (Cushman and Todd, 1946); the Red Bluff Clay at Red Bluff, Mississippi (Cushman and Todd, 1948); the Red Bluff Clay at Little Stave Creek, Alabama (recorded as *Raphanulina tuberculata* by Bandy, 1949); the Mint Spring Marl Member of the Marianna Limestone at its type locality near Vicksburg, Mississippi (Todd, 1952); the Glendon Limestone Member and the typical marl member of the Byram Formation at various Mississippi localities, where its " . . . rather widely spaced, blunt, stalk-like projections rather than true spines . . . " were noted (Todd, 1952); the Red Bluff Clay at Hiwannee, Mississippi (Deboo, 1965); and, from the Paynes Hammock Formation on the Chickasawhay River, near Waynesboro, Mississippi (Poag, 1966).

The latter author assumed that the thick apertural mound illustrated on plate 2, figures 35 and 36 (Poag, 1966), was merely an anomalous, secondarily deposited calcite mass which obscured the radiate globuline aperture.

In addition to these reported occurrences, the writer has examined excellent specimens from the Red Bluff Clay at Hiwannee, Mississippi (pl. 9, fig. 4), and at Little Stave Creek, Alabama (locality 63 of Bandy, 1949); the Mint Spring Marl Member of the Marianna Limestone at its type locality near Vicksburg, Mississippi (pl. 9, fig. 3); the Byram Formation at its type locality, Byram, Mississippi; the Chickasawhay Formation at Taylor Mill Creek, near Waynesboro, Mississippi (pl. 8, figs. 1-10); and, from the the Chickasawhay Formation near Millry, Alabama (pl. 1, figs. 1-9; pl. 4, figs. 1-10, the holotype, paratypes, and topotypes).

Two species which may be synonymous with *Vasiglobulina alabamensis* have been reported from the Eocene Yazoo Clay. Bandy (1949) recorded *Raphanulina tuberculata* (d'Orbigny) from Little Stave Creek, Alabama. Deboo (1965) listed *Globulina inaequalis caribaea* Reuss from the Pachuta Marl Member at Shubuta Hill, Clarke County, Mississippi. The illustration of each is similar to *Vasiglobulina alabamensis,* but at present the writer cannot confirm their identity. The Gulf Coast stratigraphic occurrence of this species is illustrated in text figure 4.

*Europe*

A number of European spinose Polymorphinidae have been illustrated and described by Cushman and Ozawa (1930). The writer has examined topotypes and supplementary material of several of these species. It is inferred from the presence of spines that some were attached in the living state. Of the species examined, all of the following possess a radiate tubular apertural system rather than radial slits and, therefore, are now placed in the genus *Vasiglobulina.*

*Topotypes Examined*

1) *Vasiglobulina tuberculata* (d'Orbigny), 1846—pl. 10, figs. 1,4.
   Locality: The Miocene *Amphistegina* Marl near Grünes Kreuz, Nussdorf, Vienna, Austria.
2) *Vasiglobulina striata* (Egger), 1857—pl. 10, figs. 3,6.
   Locality: The Miocene at Blindham, near Ortenburg, Lower Bavaria.
3) *Vasiglobulina variata* (Jones, Parker, and Brady), 1866—pl. 10, fig. 13.
   Locality: The Pliocene Coralline Crag of Sutton, Suffolk, England.

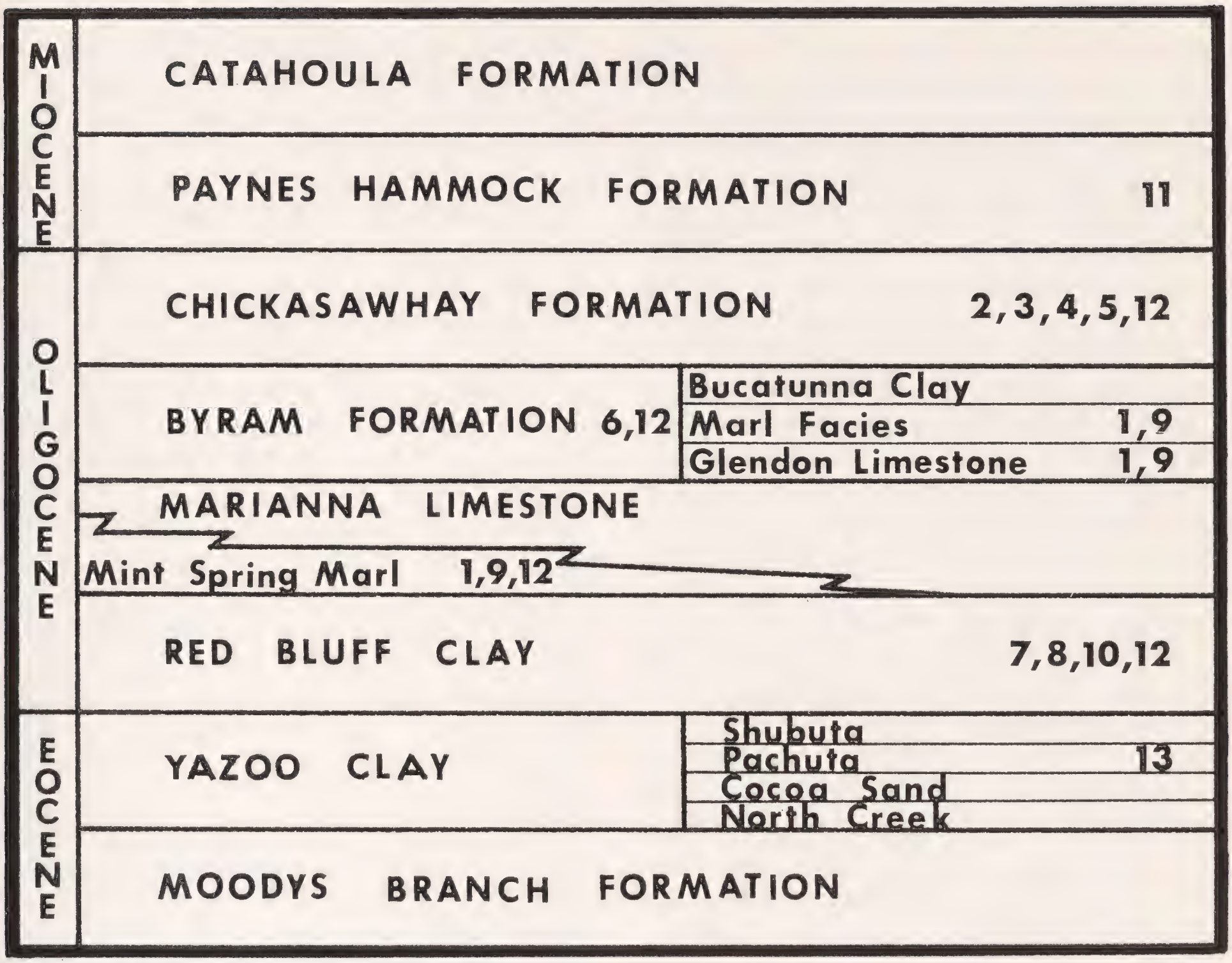
All specimens are deposited in the Chevron Oil Company Collection, New Orleans, Louisiana.

*Supplementary Material Examined*

1) *Vasiglobulina punctata* (d'Orbigny), 1846—pl. 10, figs. 2,5.
   Locality: The Pliocene Coralline Crag of Sutton, Suffolk, England; the Stampien beds at Jeurre, France; and specimens, possibly conspecific from the Pliocene near Piacenza, Italy.
2) *Vasiglobulina tuberculata?* (d'Orbigny), 1846—pl. 10, fig. 14.
   Locality: Specimens, possibly conspecific from the Pliocene near Piacenza, Italy.

All specimens are deposited in the Chevron Oil Company Collection, New Orleans, Louisiana.

In addition, on the basis of descriptions and illustrations, the following species are tentatively assigned to *Vasiglobulina*:




TEXT FIGURE 4

Stratigraphic distribution of *Vasiglobulina alabamensis* in the central Gulf Coast.
1 = Cushman, 1922b
2 = Howe, 1934
3 = Cushman and McGlamery, 1938
4 = Cushman and McGlamery, 1939
5 = Cushman and McGlamery, 1942
6 = Cushman and Todd, 1946
7 = Cushman and Todd, 1948
8 = Bandy, 1949
9 = Todd, 1952
10 = Deboo, 1965
11 = Poag, 1966
12 = Poag, this paper
13 = Unconfirmed specimens
[see Addendum, p. 70]

*Guttulina schafferi* Cushman and Ozawa, 1930; Austrian Miocene.
*Globulina gibba ornata* (Karrer), 1868; Austrian Miocene.
*Globulina inaequalis spinata* Cushman and Ozawa, 1930; German Oligocene.
*Globulina gibba fissicostata* Cushman and Ozawa, 1930; German Oligocene.
*Globulina gibba verrucosa* Cushman and Ozawa, 1930; French Eocene.

One stoutly spinose species, *Globulina lacrima ericia* Cushman and Ozawa, is recorded from the Cretaceous near Cambridge, England. The external spinose character is vasiglobuline, but further examination is required to determine its apertural type.

The geologic range of *Vasiglobulina,* therefore, is firmly established from the upper Eocene to the Pliocene Epoch. Further investigation of described species may extend the range from the Cretaceous Period to the Holocene Epoch. It is geographically confined to the U. S. Gulf Coast and Western Europe between latitudes 30° and 60° North.

## X. SUGGESTIONS FOR FURTHER INVESTIGATION

Two noteworthy areas for future investigation were revealed during the course of this work. First of all, it is apparent that several apertural systems occur within the Polymorphinidae in addition to the vasi-

globuline and radiating slit types. A thorough reassessment of the entire group is needed, including a re-examination of the type species of presently accepted genera and their type specimens. In particular, it is quite probable that "*Globulina gibba*," which has for over forty years erroneously been considered the type species for this genus, possesses a tubular rather than a slit-like apertural system (see Poag and Skinner, 1968). Secondly, detailed knowledge of the intriguing variety of foraminiferal attachment modes is meager. Among the numerous reports of attached species, the precise mechanism of attachment has rarely been given more than casual thought. Cushman (1922a), for example, described a Holocene specimen of "*Globulina caribaea*" from the Dry Tortugas region, as attached to a calcareous fragment by "stolon-like processes." The writer has examined similar Holocene specimens from the Gulf of Mexico, whose attaching "stolon like processes" are acicular spines similar to those of *Vasiglobulina alabamensis*. A diligent probe into this poorly understood phenomenon of foraminiferal attachment should yield rewarding results.

## XI. Acknowledgments

The writer wishes to thank W. H. Akers, H. A. Elliot, G. S. Robinson, W. P. S. Ventress, and M. A. Vickers of the Chevron paleontological staff for reviewing the typescript and offering astute criticism. Mr. P. E. Koeppel of Chevron designed the tilt table used for stereophotomicrography and provided technical advice during this process. The editorial committee made numerous suggestions which have been incorporated into the final form of this paper; among them, Zach M. Arnold and Jere H. Lipps deserve particular acknowledgment for their careful editing and expert opinion. Special thanks are due R. L. Parsley of Tulane University whose stimulating course in Invertebrate Paleozoology provided impetus for the investigation of foraminiferal attachment. The research was carried out under the supervision of Hubert C. Skinner of Tulane University, who also provided editorial advice. Henry V. Howe of Louisiana State University (retired) and W. H. Akers kindly provided samples. Richard Cifelli of the U. S. National Museum kindly loaned Cushman and McGlamery's type specimens. All hypotypes are deposited at the U. S. National Museum. Chevron Oil Company has granted permission to publish.

## XII. Methods of Study

Light photomicrographs were taken on a Bausch and Lomb Dynazoom Laboratory Microscope using Polaroid Polapan 400, type 32 black and white film. Three Nicholas illuminators were used for reflected light. Whole specimens were dyed with green food coloring and mounted with gum tragacanth on clear glass slides. Thin sections were mounted in Lakeside 70 thermoplastic and ground under a low power binocular stereomicroscope. For stereopairs, the angle of tilt between exposures was not measured. Each specimen was tilted between exposures so that a distance of approximately twice the diameter of the field of vision (at 90 X magnification) was traversed by the specimen.

Scanning electron photomicrographs were taken through the courtesy of the JEOLCO (U.S.A.), Inc. during a demonstration of their JSM-2 instrument at the 1968 annual convention of EMSA in New Orleans. Specimens were not coated.

## Addendum

While this paper was in press, *Vasiglobulina alabamensis* was identified from the Forest Hill Sand at St. Stevens Quarry, near Jackson, Alabama, and from the Moodys Branch Formation at its type locality near Jackson, Mississippi. The Moodys Branch specimen (TGC 13-1) is the oldest known to date, and extends the range of this species and the genus into the upper Eocene.

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# THE PLIOCENE-PLEISTOCENE BOUNDARY IN THE GULF COAST REGION

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## Introduction

Beard and Lamb (1968) focused renewed attention on the Gulf Coast Plio-Pleistocene boundary by describing the stratigraphic sequence of planktonic foraminifera in a piston-core recovered from one of the Sigsbee Knolls in the Gulf of Mexico. Upon this single core they base the late Neogene biostratigraphy for the entire Gulf of Mexico region. This is ill advised especially since the authors fail to reconcile their data with information available in published reports. The following comments are offered with the hope that a clearer perspective can be gained.

1) *Previous Gulf Coast data are ignored.*

To ignore prior published ranges of Neogene planktonic foraminifera from the Gulf Coast area is not in the best interest of objectively deciphering the geologic history of this region. Among others, Poag and Akers (1967) presented data gathered from hundreds of well samples (both rotary cuttings and cores) from numerous locations widely scattered along the Louisiana continental shelf. Some of the foraminiferal ranges listed by Poag and Akers (1967) are compared below with those of Beard and Lamb (1968).

2) *Contradictory interpretations of paleotemperature changes across proposed Pliocene-Pleistocene boundaries have not been satisfactorily resolved.*

Beard and Lamb (1968) express little doubt that the transition from a warm late Pliocene to a cool early Pleistocene is represented by the extinction level of *Globoquadrina altispira* which . . . corresponds closely with the disappearance of other warm-water species such as *G. venezuelana, Globorotalia menardii,* and *Globigerinoides*

*obliquus extremus,* and with the first appearance of the cold-water immigrant species *Globorotalia inflata.* Since, however, such precision is unwarranted by the species range data that Beard and Lamb (1968) present, the choice of *G. altispira* as the marker of the Pliocene-Pleistocene boundary seems rather arbitrary [see figure 5 (Jamaica), and figure 6 (Sigsbee Knoll core) of Beard and Lamb (1968)]. Moreover, Poag and Akers (1967) show that the dextral *G. menardii* group does not disappear at the *G. altispira* horizon, but persists along with *G. obliquus extremus* above *G. altispira* to the extinction of *G. miocenica,* and *G. inflata* occurs below the extinction of *G. altispira.*

A more convincing reflection of cooling surface waters based on planktonic foraminifera occurs at the extinction of the warm-water species *G. miocenica* and *G. obliquus extremus* (Poag and Akers, 1967), which is associated with a distinct increase in the frequency of the cool tolerant species *G. truncatulinoides* and *G. inflata,* the change in coiling direction of the *G. menardii* group upward from dextral to sinistral, and the major reduction in frequency of species and individuals of *Discoaster.* The fact that McIntyre *et al.* (1967) interpret the changes in the coccolithophorid population across the Ericson boundary (which corresponds to the boundary of Poag and Akers, 1967) as a shift upward from cool to warm water contradicts Ericson's and the present writer's interpretation of the planktonic foraminiferal data. In the present state of knowledge, however, the Coccolithophoridae are no more reliable as paleotemperature indicators than planktonic foraminifera. The foraminiferal data should not be simply ignored as Beard and Lamb (1968) have done. It is significant that there is not complete agreement among the Lamont scientists regarding the paleotemperature changes across the Ericson boundary as Beard and Lamb (1968) have implied. Ericson and Wollin (1968) recently reaffirmed their belief, based on planktonic foraminifera, that the first occurrence of abundant *G. truncatulinoides* and the major extinction of *Discoaster* reflect cooling of surface waters during the Nebraskan glacial period.

3) *The charted Pliocene-Pleistocene boundary of Poag and Akers (1967) is similar to that of Beard and Lamb (1968).*

Although Beard and Lamb (1968) state without elaboration that the Miocene-Pliocene boundary of Poag and Akers (1967) is a close approximation of the Pliocene-Pleistocene boundary of Beard and Lamb (1968), it is clear upon careful comparison of the respective range charts that this is a serious misinterpretation. The extinction of *G. altispira,* which is used by Beard and Lamb (1968) to mark the Pliocene-Pleistocene boundary, the extinction or disappearance of *G. venezuelana, G. obliquus extremus, G. multicamerata,* and the uppermost shift in coiling direction of the *G. menardii* group, all occur at or near the Pliocene-Pleistocene boundary in both charts. Above all, the persistent presence of abundant *G. nepenthes* well above Poag and Akers's (1967) Miocene-Pliocene boundary refutes a Pleistocene age for this section.

Two observations may clarify the cause of Beard and Lamb's (1968) misinterpretation. First, a comparison of the vertical scales of the respective range charts can be confusing. The vertical thickness represented in the chart of Beard and Lamb (1968) is only 250 cm, while the vertical thickness in that of Poag and Akers (1967) is several thousand feet. The charted distance between the extinction of *G. altispira* and *G. miocenica* in Beard and Lamb's (1968) chart is one inch, which represents a true thickness of 44 cm. The same two horizons on Poag and Akers's (1967) chart are less than a centimeter apart, but the true thickness represented is several hundred feet. Secondly, Poag and Akers's (1967) comparison of their Miocene-Pliocene boundary with that of Bandy (1964) may have been misleading. It should be noted that Poag and Akers (1967) only tentatively accepted Bandy's boundary, and there is growing doubt that the two are isochronous.

In order to demonstrate more clearly the similarity of sequences in the two respective range charts, it is pertinent to establish the presence of *G. margaritae* and *P. primalis* in the offshore Louisiana section. Several authors have shown that these species become extinct in or near the middle Pliocene (Banner and Blow, 1967; Parker, 1967; Beard and Lamb, 1968). The extinction levels of these species occur above the Miocene-Pliocene boundary of Poag and

Akers (1967) at relative points similar to those given by Beard and Lamb (1968).

If one should accept at face value, then, the species ranges given by Beard and Lamb (1968), the Pliocene-Pleistocene boundary of Poag and Akers (1967) is near to, but slightly younger than the Pliocene-Pleistocene boundary of Beard and Lamb (1968). The precise ranges charted by Beard and Lamb (1968) must be used with caution, however, for the reasons listed below.

4) *Discrepancies in the charted foraminiferal ranges may be due to sampling interval and non-standard species identification.*

Beard and Lamb (1968) studied samples representing a total thickness of 90 cm of their core, while 232 cm of core between sample intervals were not examined; the amount of core not examined exceeds 2.5 times the amount examined. Furthermore, 150 cm above and 150 cm below the sampled interval were not studied in detail. This, in light of the discontinuous occurrence of many of the species charted by Beard and Lamb (1968), is reason to suspect that the charted ranges may not represent the true ranges of such species as *G. altispira, G. truncatulinoides, G. inflata,* and others. As a case in point, Beard and Lamb (1968) report that "*G. miocenica,* usually present in the late Pliocene is not recorded until the Pleistocene." The disappearance of species in the upper samples is especially subject to question since the foraminifera from the youngest 150 cm were not recorded. One wonders if the charted disappearance of *G. miocenica,* for example, should be considered any more reliable than that of the living species *P. obliquiloculata* which Beard and Lamb (1968) show disappears earlier than *G. miocenica.*

The improbability that true ranges of foraminiferal species (especially those with low frequency of individuals and/or discontinuous stratigraphic occurrence) will be represented in any single deep-sea core, well, or outcrop is amply demonstrated by the published record (*e.g.*, Parker, 1964, 1967; Ericson, Ewing, and Wollin, 1963; Bolli and Bermudez, 1965; Bolli, 1966; Berggren *et al.*, 1967; Bolli *et al.*, 1968; Ericson and Wollin, 1968). This and the ever-present problem of standard species identification must be given serious consideration before basing precise Neogene correlations in the Gulf of Mexico region on core 64-A-9-5E.

5) *McIntyre et al. (1967) moved the Pliocene-Pleistocene boundary below the boundary of Ericson, Ewing, and Wollin (1963), not above it.*

Beard and Lamb (1968) erroneously state that McIntyre, Bé, and Preikstas (1967) revised the Pliocene-Pleistocene boundary upward to the base of the next cool period above the boundary of Ericson *et al.* (1963). They further note that ". . . shifting the boundary upward half a climatic cycle puts it a full cycle above the base of the Nebraskan of Gulf Coast usage, or near the base of the Kansan." In reality, however, McIntyre *et al.* moved the Pliocene-Pleistocene boundary *below, not* above the Ericson boundary. They implicitly state (p. 23) that the ". . . best placement of the [Ericson] boundary is that of Akers (1965), *i.e.* between the Nebraskan Glacial and Aftonian Interglacial stages of the early Pleistocene."

It is clear that misrepresentation of this sort is not consistent with Beard and Lamb's (1968) intention ". . . to determine the most suitable horizons for placement of the Miocene-Pliocene and Pliocene-Pleistocene boundaries with respect to the planktonic succession. . . ."

6) *The extinction of G. altispira under the Louisiana continental shelf occurs in the Aftonian of Akers and Holck (1957).*

Transcending the discussion above, Beard and Lamb's (1968) use of *G. altispira* as the Pliocene-Pleistocene boundary marker in the Gulf Coast presents an insurmountable paradox. In the offshore Louisiana area this species becomes extinct in the lower part of the shale unit which Akers and Holck (1957) and Akers and Dorman (1964) have referred to the Aftonian interglacial [Beard and Lamb (1968) conclude that this shale unit is even younger]. Obviously, its extinction can not then be coincident also with the base of the Nebraskan Glacial that Beard and Lamb (1968) place well below the Aftonian of Akers and Holck (1957). The writer must conclude that Beard and Lamb's (1968) reported disappearance of *G. altispira* is lower than its extinction as seen in offshore Louisiana.

(*Continued on page 90*)

# THE GENUS *TRAJANA* (MOLLUSCA: GASTROPODA) IN THE NEW WORLD

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## I. Abstract

The nassarioid gastropod genus *Trajana* s.s. includes those species with a closed siphonal canal and a circular aperture, surrounded by a raised peristome. There are but four species in the fossil record of the New World, occurring in the upper Miocene of North Carolina, Florida, Mexico, and Peru, and the Pliocene of Ecuador. One of these four is a new species: *T. veracruzana* E. H. Vokes, from the upper Miocene Agueguexquite Formation of Mexico, and represents the first record of the genus in the "Tertiary Caribbean Province," linking the eastern United States and the western South American occurrences. Another new species, from the middle Miocene Gatun Formation of Panamá, is believed to be ancestral to the *Trajana* s.s. group as it possesses an open siphonal canal and denticulations within the subcircular aperture with a raised peristome like that of *Trajana* s.s. Because of the fundamental differences this new species is made the type of a new subgenus with the name *Trajana* (*Nerva*) *woodringi* E. H. Vokes.

In addition to the fossil species, there are two Recent species of *Trajana* s.s. found off the coast of western Mexico. All species are treated systematically.

## II. Introduction

Those gastropods possessing a short, slightly recurved, closed siphonal canal, a circular aperture surrounded by a raised peristome, and a single terminal varix have presented a problem to writers for many years. Dall (1910, p. 32-33) suggested that they be referred to the genus *Hindsia* A. Adams, 1851, which was a troubled group from the start. Dell (1967, p. 309-310) has summarized the problem nicely, stating: "The name *Hindsia* had an uncertain introduction, and has had a chequered subsequent history in molluscan nomenclature. Almost before it had been properly proposed it had been listed as a synonym of *Nassaria* and its subsequent history has been linked with this latter generic name." Dell presented a resume of the tangled history of the name, which will not be repeated here, but concluded by naming "*Hindsia nivea* Pfeiffer" as the type species of the genus, thus removing it from consideration for the species under discussion.

These species are not left without a name,

Editorial Committee for this Paper:

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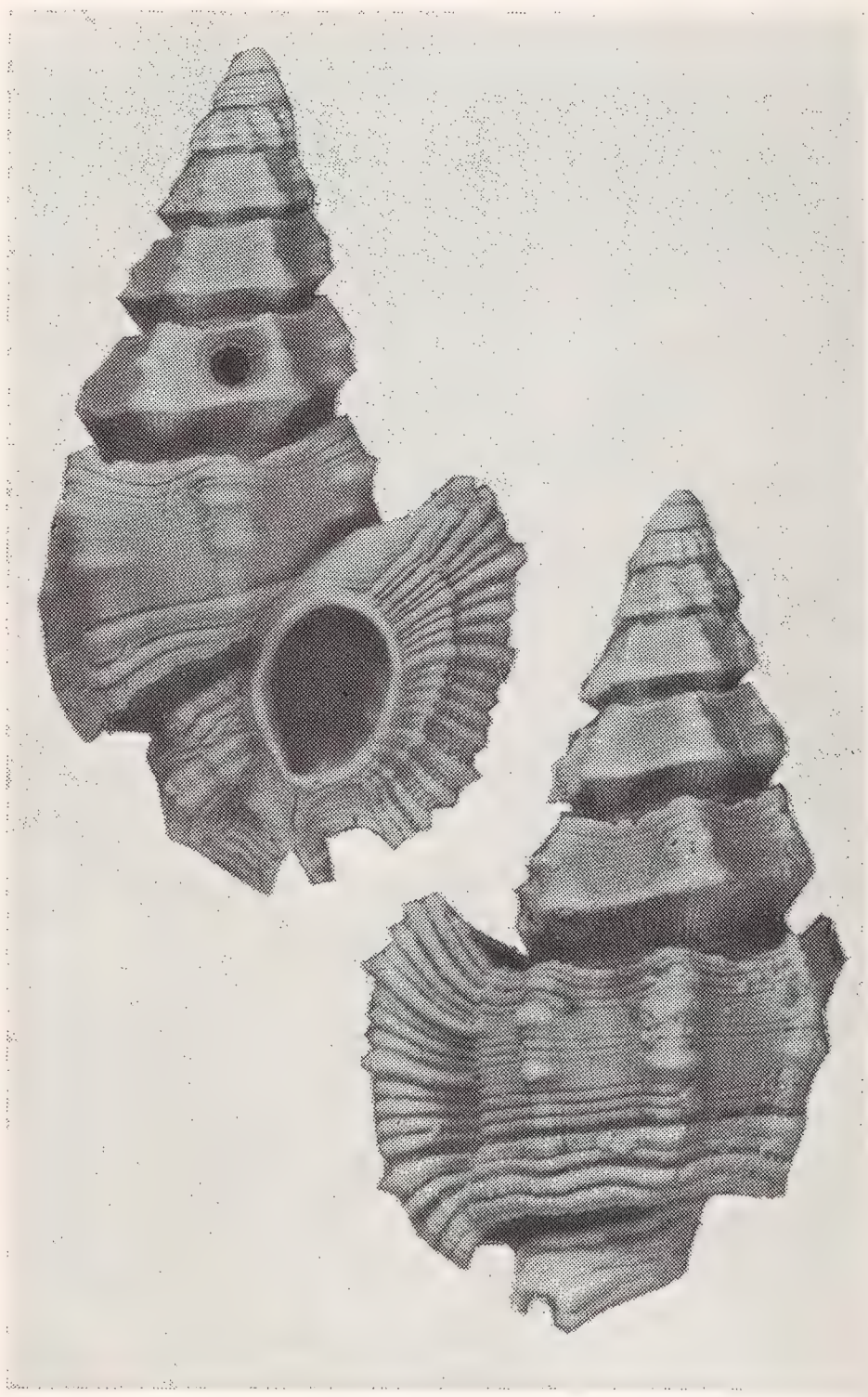
Text figure 1. Radula of *Trajana acapulcana* (Pilsbry and Lowe). Magnification approximately × 150. (From photograph by Myra Keen.)

however, for Gardner (1948, p. 221) proposed the genus *Trajana* for a species of the group from the upper Miocene of North Carolina, with the monotype *Trajana pyta.* She was of the opinion that this new genus was most closely related to the muricid subgenus *Hadriania,* which is placed in the subfamily Tritonaliinae (see Vokes, 1964, p. 20), the name *Trajana* being derived from that of the Roman emperor Trajan, who immediately preceded Hadrian. The writer was originally of the same opinion due to the closed siphonal canal, but additional work proved the group to be most closely related to the Nassariidae. The radula of the Recent species *T. acapulcana* (Pilsbry and Lowe) is nassarioid (see text fig. 1) and the nature of the closure of the canal is different from that in the Tritonaliinae. In the latter group a thin plate extends from the columellar wall over the siphon, meeting the outer lip at the abaxial edge. But in *Trajana* the outer lip folds over and joins the columellar lip at the adaxial edge, so these can truly be said to be analogous structures with no relationship other than function.

*Trajana* s.s. is a small group, there being only four fossil species and two Recent species known exclusively from the New World. The fossil species are upper Miocene and Pliocene in age, ranging from North Carolina to Peru. The two Recent forms occur on the west coast of Mexico. The shell figured by Reeve (1844, pl. 20, fig. 96) as "*Triton nassoides* Gray," from the Philippines, is not that species but probably is a specimen of one of the West Mexican species of *Trajana.* The shell originally figured as "*Triton*" *nassoides*, in Griffith and Pidgeon (1834, pl. 41, fig. 4), is not a *Trajana* but is probably the species subsequently named "*Triton*" *acuminatus* by Reeve (1844, pl. 14, fig. 59), and is a true *Hindsia.*

Another west coast species was named "*Hindsia*": "*Hindsia*" (*Neoteron*) *ariel* Pilsbry and Lowe, 1932, type of *Neoteron* (text fig. 2). This species is clearly related to the *Trajana* line, but is so completely bizarre that it seems better to separate it as a distinct, though monotypic, genus. *Neoteron ariel* is distinguished from the typical *Trajana* by the expanded wing-like terminal varix and by a conspicuous nassarioid fossa circling the base of the body whorl. The *Trajana* species have only a slight tendency toward this fossa. It may be descended from the Miocene *Trajana veracruzana,* n. sp. The two species share a peculiar channeled suture (see pl. 1, fig. 1b) not seen in any other species of *Trajana.* The spiral ornamentation crossing the terminal varix is markedly similar in *Neoteron* and *Trajana,* suggesting that *Neoteron* is a derivative form. However, there is a peculiar lamellar



Text figure 2. *Neoteron ariel* Pilsbry and Lowe. ANSP 155564 (holotype); height 9.9 mm, diameter 5.6 mm; locality: Corinto, Nicaragua. × 6.

axial sculpture more akin to the Muricidae. This is particularly well developed on the apertural face of the terminal varix, which together with the wing-like expansion of this varix combines to give a muricid aspect to the shell.

The genus *Trajana* is almost certainly descended from a *Nassarius*-like ancestor. In the Gatun Formation of Panamá there is a species that strongly suggests *Trajana* in having marked axial folds, a subcircular aperture surrounded by a raised peristome, a high spire, and a short recurved canal. However, the canal is open and there are typical *Nassarius* denticulations within the aperture, on both inner and outer lips. The genus *Trajana* has a completely smooth aperture. Because of these very basic differences this ancestral form cannot in good conscience be placed in *Trajana* s.s.; therefore, a new subgenus *Nerva,* named for the Roman emperor who preceded Trajan,* is here proposed.

## III. Acknowledgments

The writer wishes to express her gratitude to Druid Wilson, U. S. Geological Survey; Myra Keen, Stanford University; and R. K. Dell, Dominion Museum, Wellington, New Zealand, all of whom worked to untangle the *Hindsia* problem. She would also like to thank the following persons who loaned material necessary to the study: Copeland MacClintock, Peabody Museum of Natural History, Yale University; H. G. Richards and R. Tucker Abbott, Academy of Natural Sciences, Philadelphia; and Mrs. R. C. Hoerle, West Palm Beach, Florida. The financial assistance of National Science Foundation Grant no. G.B. 6048 is gratefully acknowledged.

## IV. Systematic Descriptions

### Phylum Mollusca
### Class Gastropoda
### Subclass Prosobranchia
### Order Neogastropoda
### Suborder Stenoglossa
### Superfamily Buccinacea

### Family Nassariidae
### Genus *Trajana* Gardner, 1948

### Subgenus *Nerva* E. H. Vokes, n. subgen.

Type species: *Trajana* (*Nerva*) *woodringi* E. H. Vokes, n. sp., Gatun Formation, Panamá, middle Miocene.

Etymology: Nerva, a Roman emperor; gender: masculine.

*Description*: Shell scalariform, high-spired; protoconch multiwhorled, smooth; axial costae strong, separated by relatively smooth interspaces; numerous spiral ribs; a single varix developed at aperture; aperture subcircular, almost entire, surrounded by a slightly raised peristome; on the interior of the outer lip a few elongate denticles and on the columellar wall several weak denticulations, together with a larger tooth at the adaptical end; siphonal canal slightly extended, recurved, open by a narrow slit.

### Trajana (Nerva) woodringi
### E. H. Vokes, n. sp.
### Plate 1, figs. 2a, 2b

*Description*: Shell moderate in size for the genus, high-spired; protoconch of two and one-half smooth whorls; ornamentation beginning gradually with small axial costae, nine on the first two post-nuclear whorls, then diminishing to seven or eight on each succeeding whorl; spiral ornamentation of small ribs, three on early whorls gradually increasing to five on penultimate and eight on body whorl, with two more on siphonal canal; where spiral ribs cross axial costae small nodes are formed, spiral ribs almost completely obsolete between the axial costae; single varix formed at apertural lip, resorbed to form axial costae with each growth-stage; aperture almost circular, surrounded by a raised peristome; interior of outer lip bearing four strong, elongate denticles; columellar wall with several small pustules and one larger tooth at adaptical end; siphonal canal slightly extended, recurved, open by a narrow slit; small siphonal fasciole developed.

Dimensions of holotype: height 14.0 mm, diameter 8.0 mm.

Holotype: USNM 646229.

Type locality: TU 757, roadcut on south side of Boyd-Roosevelt Highway at junction of road to "Refineria Panamá, S. A.," just east of Cativa, Province of Colón, Panamá.

*Occurrence*: Gatun Formation, Panamá; middle Miocene.

*Figured specimen*: USNM 646229 (holotype). Other occurrences: TU locality nos. 958, 959.

*Discussion*: This new species seems to be intermediate between the typical *Trajana* and some *Nassarius*-like ancestor. The nassarioid traits include the denticulations on the inner and outer lips and the short, re-

*Nerva: 96-98 A.D.; Trajan 98-117 A.D.; Hadrian: 117-138 A.D.

curved, open siphonal canal. The *Trajana* characteristics are the strong axial costae, the circular, almost entire aperture, surrounded by a raised peristome, the terminal varix, and the very high spire. There are four specimens in the type lot, all from the same general area, which is approximately locality 138b of Woodring (1959, p. 148).

The geographic position of this ancestral form, in the Panamanian area, is ideal from the standpoint of subsequent distribution both north to Mexico and the United States and south to Peru and Ecuador.

## Subgenus TRAJANA s.s.

*Trajana* GARDNER, 1948, U. S. Geol. Surv. Prof. Paper 199, p. 221.

Type species: *Trajana pyta* Gardner, by original designation.

*Description*: "Shell more or less scalariform in outline. Spire elevated. Protoconch small, unsculptured. Axial costae prominent and somewhat varicose but not foliated or spinose. Spiral sculpture dense. Anal fasciole strongly arched. Aperture regularly elliptical in outline; inner lining continuous. Outer lip varicose, nonlirate within. Inner lip evenly concave, nonplicate. Anterior canal closed, short, and rather feebly recurved. Umbilical chink closed." (Gardner, 1948)

## TRAJANA (TRAJANA) PYTA Gardner
Plate 1, figs. 3a, 3b

*Trajana pyta* GARDNER, 1948, U. S. Geol. Surv. Prof. Paper 199, p. 221, pl. 29, figs. 10, 11.
*Hindsia pyta* (Gardner). OLSSON, 1967, Tertiary mollusks south Florida and Caribbean, p. 35, pl. 6, fig. 8.

*Description*: "Shell scalariform, spire elevated, apex acute, body broad and relatively low, abruptly constricted at the base. Whorls strongly convex, tabulated posteriorly, rapidly increasing in size, approximately 7. Protoconch of 1½ to 2 small, unsculptured coils, the earlier largely immersed. Axial sculpture initiated at the beginning of first turn of conch with obtuse vertical riblets that rapidly develop into broad, rounded, strongly elevated, undulatory costals; 7 or 8 on the whorls of the spire, equal in size and spacing except on the final half turn, most prominent on the periphery of the whorl and tending to alternate in arrangement. Spiral sculpture of sharply elevated lirations that override the costals and are equally prominent on the costal and intercostal areas; spirals initiated simultaneously with the axial sculpture by the appearance of the 2 lirae that crown the periphery of the whorl; first one, and then a second finer threadlet introduced behind the periphery and later either 1 or 2 lirae in front of the periphery, those nearest the sutures the least conspicuous; primaries on the body whorl 8 or 9 including the 2 on the shoulder; finer secondaries commonly introduced midway between the primaries, that at the base of the body approximating in strength the primary behind it. Anterior siphonal canal closely sculptured with 9 or 10 sharply elevated lirae, the 1 or 2 posterior spirals set a little apart from those in front of them. Siphonal canal cut off from the base of the body whorl by a convex area that is strongly rippled by the axial costae but not spirally threaded; delicate filamentary incrementals visible under magnification in the interspiral areas. Suture line distinct, impressed, crenulated by the axials of the preceding whorl. A narrow shoulder in front of the suture strongly defined, persistent almost to the apex; concave near the aperture, sloping and feebly undulated by the axials on the earlier volutions and occasionally threaded with a single fortuitous spiral near the anterior margin. Aperture elliptical, smoothly and evenly glazed within, with no trace of any angularity either anteriorly or posterioly nor of any denticulation or rugosity on either the outer or the inner lip. Labrum strongly varicose, the varix obtuse and prominent, encroaching posteriorly on the preceding whorl. Anterior canal closed, short, and rather feebly recurved. Umbilical chink not visible." (Gardner, 1948.)

Dimensions of holotype: height 17.3 mm, diameter 10.8 mm.

Holotype: USNM 497151.

Type locality: Natural Well, two miles southwest of Magnolia, Duplin County, North Carolina (= TU 376).

*Occurrence*: Duplin Marl, North Carolina; Jackson Bluff Formation and Pinecrest Beds, Florida; upper Miocene.

*Figured specimen*: USNM 646230; height 16.4 mm, diameter 9.2 mm; locality TU 730. Other occurrences TU locality nos. 60, 523, 729, 932, 933.

*Discussion*: Although none of the species of *Trajana* is common, *T. pyta* is the most nearly common and widespread of the group. The species was described from Natural Well, North Carolina, and was said to be based on two specimens. No specimens have been collected by the writer at this locality (= TU 376). A single specimen, in the collection of Mr. Paul Huddleston, of New Orleans, has been found at Jackson Bluff, Ochlochonee River, Florida (= TU 60), type locality of the Jackson Bluff Formation. Another single specimen was collected by the writer at TU 523, which represents the youngest known occurrence of the genus in the United States, for this locality is in the uppermost level

of the Pinecrest Beds, immediately below the overlying Caloosahatchee Formation. This is approximately the same locality where Olsson (1967, p. 35) noted that specimens had been found by Hughes. Only along the Kissimmee River (or Canal), in the vicinity of Fort Basinger, Florida (TU 730 & 932), is the species really abundant, with over 200 specimens collected. A few specimens have been found at the northernmost end of TU 729, in beds correlative to those farther north at Fort Basinger, and a few have been taken at TU 933, which is south of Lake Okeechobee, on "Alligator Alley." All of these occurrences are in the older strata of the Pinecrest Beds.

## TRAJANA (TRAJANA) LAQUEORATA (Spieker)

Plate 1, fig. 5

*Murex laqueoratus* SPIEKER, 1922, Johns Hopkins Stud. Geol., no. 3, p. 51, pl. 2, fig. 4 (spelled *laquoratus* in plate expl.).

*Murex laqueoratus* Spieker. HANNA AND ISRAELSKY, 1925, California Acad. Sci., Proc., (Ser. 4) v. 14, no. 2, p. 53.

*Murex laqueoratus* Spieker. OLSSON, 1932, Bulls. Amer. Paleontology, v. 19, no. 68, p. 31.

*Description*: "Shell small, turreted, fairly stout. Whorls about six in number, the first two smooth, the remainder delicately sculptured and convex. Sculpture of regular longitudinal folds, eight to the whorl, which are negligible at the suture, increasing rapidly to full strength at the mid-line of the whorl, and decreasing again. On the body whorl all except the last two continue over the base as narrow rounded folds; the last two die out just below the shoulder. Spiral sculpture of fine threads, about six to the whorl, with occasional interstitial threads above or below the periphery of the whorls; there the two central threads are prominent, forming a band which heightens the prominence of the nodes on the longitudinal ridges. On the body whorl there are twelve primary threads between the band and the base, with occasional interstitial threads. Aperture almost circular, smooth within, with a raised lip and a fan-like flare bordering the outer lip over which the spiral sculpture continues to the raised peristome. The canal is very narrow, open and short. Columella almost straight." (Spieker, 1922)

Dimension of holotype: height 17.8 mm, diameter 11.3 mm.

Holotype: Yale Peabody Museum no. 502.

Type locality: Near mouth of Quebrada Tucillal, just north of Zorritos schoolhouse, Zorritos, Peru (Olsson, 1932, p. 7).

*Occurrence*: Tumbes Formation, Peru; upper Miocene.

*Figured specimen*: YPM 502 (holotype).

*Discussion*: At the time Spieker redescribed the Nelson Collection of fossils from the vicinity of Zorritos, northern Peru, the exact locality for these specimens was not known and Spieker noted (1922, p. 12-13): "The matrix in which most of the specimens so far collected [by J. T. Singewald, Jr.] occur is far too resistant to permit the extraction by any known means of specimens at all susceptible to injury through moderate violence; . . . Loose matrix on some of the specimens in the Nelson collection indicates that there are probably some localities at which the sands have not been cemented." Olsson subsequently relocated the Nelson locality (1932, p. 7 & 30) and observed that it was actually a down-faulted block of upper Miocene Tumbes Formation that carried Nelson's fossil fauna and not part of the Zorritos Group as supposed by Spieker. Originally spelled "Tumbez" by Olsson, the correct spelling is now "Tumbes" according to the *Lexique Stratigraphique International* (1956, v. 5, fasc. 5b, p. 110).

Although the siphonal canal on the unique type specimen of *T. laqueorata* is open, this seems to be the result of breakage and there is little doubt that in life the canal would have been sealed. The alternating large and small spiral ribs and the smooth aperture indicates a closer alliance with the typical *Trajana* group than with the ancestral *Nerva* form.

## TRAJANA (TRAJANA) VERACRUZANA E. H. Vokes, n. sp.

Plate 1, figs. 1a, 1b, 1c

*Description*: Shell small for the group, high spired; protoconch of two and one-half, smooth, bulbous whorls, seven post-nuclear whorls in adult; cancellate ornamentation beginning gradually and consisting of axial costae and spiral ribs; twelve axial costae on the first post-nuclear whorl, decreasing to about eight on medial whorls then increasing to about twelve again on the penultimate but becoming almost completely obsolete on body whorl; three spiral ribs on first whorl gradually increasing to twelve major ribs with several smaller intercalated riblets on the body whorl and an additional eight riblets on the siphonal canal; on the medial whorls the two ribs at the periphery larger than those above and below, becoming approximately the same on the body whorl; the rib at the shoulder greatly raised causing suture to be deeply set into a narrow channel formed by the rib at the

shoulder and the peripheral rib of the preceding whorl; one terminal varix at aperture with a deep excavation behind it; aperture circular, entire, surrounded by a raised peristome, smooth on the interior; siphonal canal short, recurved, closed.

Dimensions of holotype: height 12.0 mm, diameter 7.2 mm.

Holotype: USNM 646231.

Type locality: TU 638, roadcut and quarry on Mexico Highway 180, 14 miles east of junction with side road into Coatzacoalcos, Veracruz, Mexico.

*Occurrence*: Agueguexquite Formation, Mexico; Pinecrest Beds, Florida; upper Miocene.

*Figured specimen*: USNM 646231 (holotype).

*Discussion*: The type lot of this small species consists of two and one-half specimens from the Agueguexquite Formation of Mexico. The form is unique in having a deeply channeled suture (see pl. 1, fig. 1b), more pronounced than that in any other species of the group. A tendency toward this type of suture is seen in the other species only immediately behind the terminal varix.

In addition to the type lot, in the U. S. Geological Survey collections made by Druid Wilson at Acline, Charlotte County, Florida (= TU 200), there are two specimens of *T. veracruzana.* The fauna at Acline is equivalent to that of the so-called "Brighton Beds" near Lake Okeechobee, and seems to represent the uppermost Pinecrest strata. The appearance of an Agueguexquite fossil in this relative position would suggest that perhaps the Mexican formation is even younger than previously believed. On the basis of the muricine species the writer has considered the Agueguexquite to be early upper Miocene in age. Correlation with the Brighton beds would indicate a late upper Miocene age for the Agueguexquite Formation. According to Mr. Wilson (personal communication) there are also other species in common between the Acline beds and the Agueguexquite.

In a paper on the Panamá land bridge as a sea barrier, Woodring (1966) noted that there are a number of genera originally found in the western Atlantic region now extinct there and surviving only in the eastern Pacific today. The geologic record of migration of these "paciphiles," as he termed them, is often lacking and as an example he stated (1966, p. 429): "Missing records are illustrated by the occurrence in Florida and North Carolina of a paciphile (*Trajana*) that is so far unknown in the western Atlantic part of the Tertiary province, although the only rational explanation is that it migrated through that part." The writer is pleased to be able to fill in one gap in the record.

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PLATE 1

(all figures X 4)

Figures Page

1. *Trajana* (*Trajana*) *veracruzana* E. H. Vokes, n. sp. ---- 79
USNM 646231 (holotype); height 12.0 mm, diameter 7.2 mm.
Locality: TU 638. Agueguexquite Fm., upper Miocene.
2. *Trajana* (*Nerva*) *woodringi* E. H. Vokes, n. sp. ---- 77
USNM 646229 (holotype); height 14.0 mm, diameter 8.0 mm.
Locality: TU 757. Gatun Fm., middle Miocene.
3. *Trajana* (*Trajana*) *pyta* Gardner ---- 78
USNM 646230; height 16.4 mm, diameter 9.2 mm.
Locality: TU 730. Pinecrest Beds, upper Miocene.
4. *Trajana* (*Trajana*) *wheeleri* (Pilsbry and Olsson) ---- 82
ANSP 14483 (holotype); height 16.5 mm, diameter 9.5 mm.
Locality: Punta Blanca, Ecuador. Canoa Fm., Pliocene.
5. *Trajana* (*Trajana*) *laqueorata* (Spieker) ---- 79
Yale Peabody Mus. no. 502 (holotype); height 17.8 mm, diameter 11.3 mm.
Locality: Zorritos, Peru. Tumbes Fm., upper Miocene.

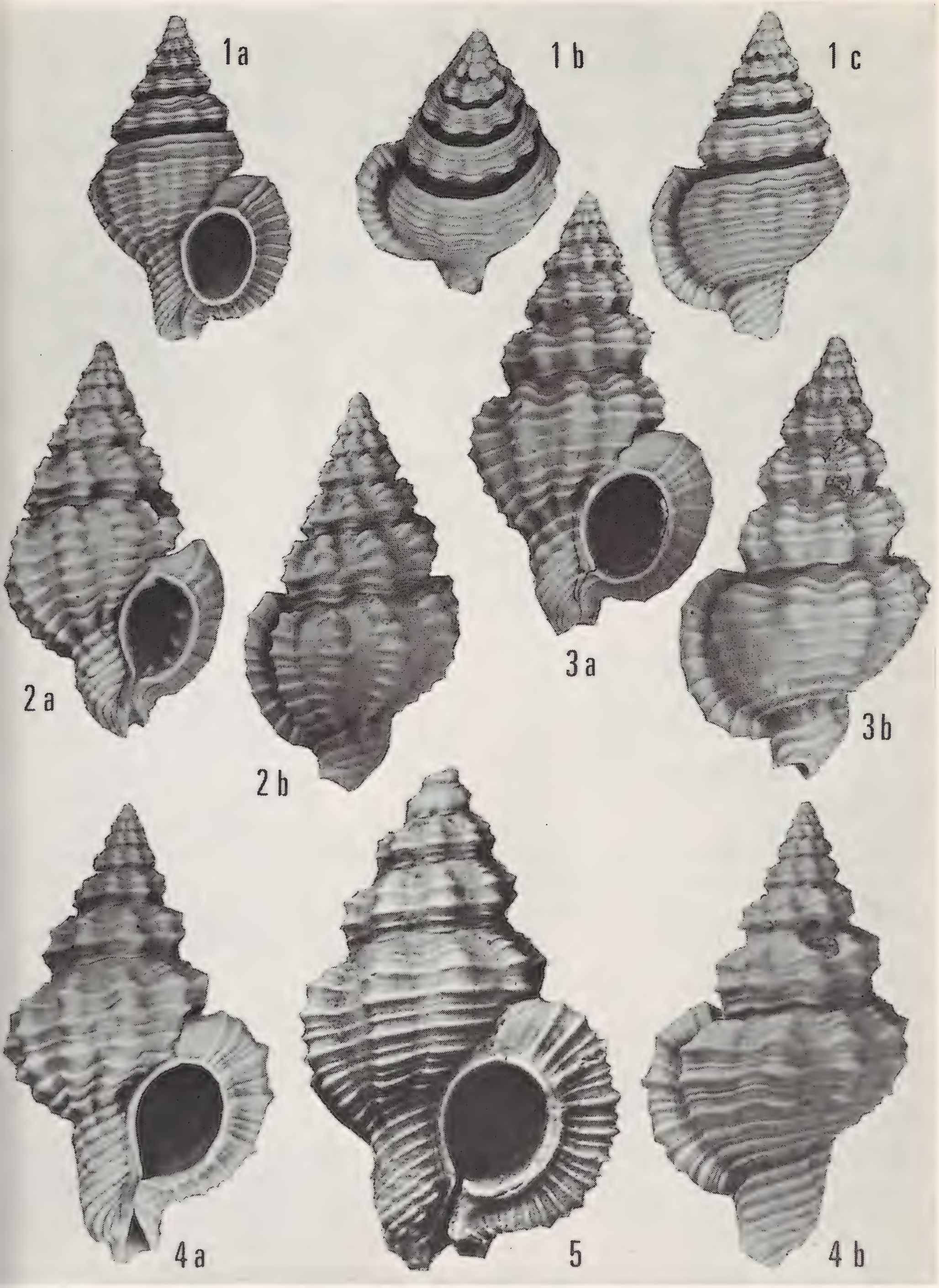


PLATE 1

### Trajana (Trajana) wheeleri (Pilsbry and Olsson)

Plate 1, figs. 4a, 4b

*Hindsia wheeleri* Pilsbry and Olsson, 1941, Acad. Nat. Sci. Phila., Proc., v. 93, p. 29, pl. 5, fig. 10.

*Description*: "Shell small, solid; whorls about 8 of which the first 2 are nuclear, smooth, except the last quarter turn which has weak spirals; the post-nuclear whorls are strongly sculptured by ribs and spirals; the sculpture of the spire-whorls consists principally of 2 strong spiral cords which form the middle of the whorls, these spirals are crossed, and rendered strongly nodose, by axial ribs; on the shoulder area, there are 2 smaller spirals with 2 others on the area between the lower suture and the lower of the 2 primary middle spiral cords; the sculpture is similar on the body-whorl with 4 spirals on the base and about 8 strong ones on the beak; there are 9 ribs on the last whorl beside the enlarged, thickened lip; on the last whorl the sutural zone becomes a deep, smooth channel which unites with another channel behind the outer lip; aperture is small, ovate, continuous with a raised, inner rim; outer lip doubling back on itself, forming a wide varix, more or less hollow within; beak long, recurved at the tip and carrying the anterior canal." (Pilsbry and Olsson, 1941)

Dimensions of holotype: height 16.5 mm, diameter 9.5 mm.

Holotype: ANSP 14483.

Type locality: Punta Blanca, Ecuador.

*Occurrence*: Canoa Formation, Ecuador; Pliocene.

*Figured specimen*: ANSP 14483 (holotype).

*Discussion*: As noted by Pilsbry and Olsson this species is closely related to *T. acapulcana* (Pilsbry and Lowe) from the Recent fauna of western Mexico. The fossil form differs in having a shorter spire and more inflated body whorl. The other differences cited by the original authors, such as the heavier lip, entire peristome, and closed canal, are due to the fact that the type of *T. acapulcana* is a juvenile specimen with an incomplete aperture.

### Trajana (Trajana) perideris (Dall)

*Hindsia perideris* Dall, 1910, Nautilus, v. 24, no. 3, p. 32.

*Hindsia* (*Hindsia*) *perideris* Dall. Keen, 1958, Sea shells of tropical West America, p. 404, fig. 554 (holotype).

*Description*: "Shell of about ten whorls, the nucleus smooth white of about two whorls, the subsequent whorls (except the last) slowly enlarging, forming a slender acute spire, the last whorl suddenly larger; sculpture of about six slightly protractive axial ribs, strong and rounded, following each other up the spire in a gently receding spiral, with much wider interspaces, most prominent at the periphery of the whorls, but traceable to the canal; these are crossed between the sutures by six rounded, subequally spaced spiral threads with much wider interspaces (the space between the posterior thread and the suture widest of all), a little swollen where they override the ribs; on the last whorl finer intercalary threads appear, and on the canal are seven or eight stronger, spirally striated cords; aperture subcircular, not lirate within, with a produced, simple peritreme, and behind it a wide, strong, rounded varix over-ridden by the spiral sculpture; canal short, closed when adult, pointed and strongly recurved. The color of the shell is mostly yellowish-white, with a basal and sometimes a sutural brownish spiral band, which shows more or less in the interior of the aperture." (Dall, 1910)

Dimensions of holotype: height 28.5 mm, diameter 15.0 mm.

Holotype: USNM 96658.

Type locality: off La Paz, Baja California, Mexico, in 21 fms.

*Occurrence*: Recent only, Gulf of California from La Paz to Guaymas, 20-30 fms.

*Discussion*: The two Recent species of *Trajana* found on the western coast of Mexico are much alike. *T. perideris* is a lighter color than *T. acapulcana* and has fewer axial ribs. The spiral rib at the periphery is stronger, giving the shell a marked angulation almost exactly at the mid-point. In some specimens there is a white spiral color band that corresponds to this peripheral angulation.

### Trajana (Trajana) acapulcana (Pilsbry and Lowe)

*Hindsia acapulcana* Pilsbry and Lowe, 1932, Acad. Nat. Sci. Phila., Proc., v. 84, p. 66, pl. 7, fig. 11.

*Hindsia* (*Hindsia*) *acapulcana* Pilsbry and Lowe. Keen, 1958, Sea shells of tropical West America, p. 404, fig. 553.

*Description*: "Shell of about 9½ strongly convex whorls, of which two are nuclear, smooth and white. Color chestnut brown, with a darker subsutural band, the intervals of ribs and much of base cartridge buff. Axial ribs rounded, crossed on the penultimate whorl by six spiral cords, the two on the periphery being stronger, swollen a little where they cross the axial ribs; on the body whorl may be counted about twenty spiral cords of varying strength, eight of which are on the canal, which is recurved and almost closed. Outer lip thin, doubling back on itself forming a wide hollow varix, crossed by the spiral sculpture, which is here emphasized." (Pilsbry and Lowe, 1932)

Dimensions of holotype: height 17.5 mm, diameter 9.7 mm.

Holotype: ANSP 155334.

Type locality: off Acapulco, Guerrero, Mexico, in 20 fms.

*Occurrence*: Recent only, off southwestern Mexico, from Acapulco to Gulf of Tehuantepec, 20 to 40 fms.

*Discussion*: This species was based on a juvenile specimen but adults show that at the same size as *T. perideris* (Dall) the two forms are distinct. *T. acapulcana* is a uniformly dark brown color and has more numerous axial costae. Otherwise the two are very close and undoubtedly both are descended from the Pliocene *T. wheeleri* (Pilsbry and Olsson) of Ecuador.

## V. Locality Data

The following are Tulane University fossil locality numbers:

60. Jackson Bluff Fm., borrow pits at Jackson Bluff, Ochlockonee River (NW ¼ Sec. 21, T1S, R4W), Leon Co., Florida.
200. Pinecrest Beds, borrow pits about one mile southwest of Acline (Sec. 29, T41S, R23E), Charlotte Co., Florida.
376. Duplin Marl, "Natural Well," sinkhole on Matthews' farm, on North Carolina Highway 11, two miles southwest of Magnolia, Duplin Co., North Carolina.
523. Pinecrest Beds, Harney Pond Canal spoil banks, six miles northwest of Florida Highway 78, Brighton Indian Reservation (NW ¼ Sec. 22, T39S, R32E), Glades Co., Florida.
638. Agueguexquite Fm., roadcut and quarry on Mexico Highway 180, 14 miles east of junction with side road into Coatzacoalcos, Veracruz, Mexico.
729. Pinecrest Beds, spoil banks on west side of Kissimmee Canal and east side of Kissimmee River, approximately ½ mile south of U. S. Corps of Engineers Structure 65-D (S ½ Sec. 33, T36S, R33E), Okeechobee Co., Florida.
730. Pinecrest Beds, embankment of Seaboard Airline Railroad, just west of Kissimmee River (NW ¼ Sec. 20, T36S, R33E), Highlands Co., Florida.
757. Gatun Fm., roadcut on south side of Boyd-Roosevelt Highway at junction of road to "Refinería Panamá, S. A.," just east of Cativa, Prov. of Colón, Panamá.
932. Pinecrest Beds, east side of Kissimmee River (*i.e.*, canal) and ½ mile south of Seaboard Airline Railroad, south of Fort Basinger (SE ¼ Sec. 20, T36S, R33E), Okeechobee Co., Florida.
933. Pinecrest Beds, material exposed during construction of "Alligator Alley," 21.5 miles east of Florida Highway 29, Collier Co., Florida.
958. Gatun Fm., hillslope on east side of road from Boyd-Roosevelt Highway to "Refinería Panamá, S. A.," about ½ km north of junction, just east of Cativa, Prov. of Colón, Panamá.
959. Gatun Fm., roadcut on road to "Refinería Panamá S. A.," about 100 mts. south of refinery gate, Prov. of Colón, Panamá.

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July 16, 1969

# PALEONTOLOGICAL NOTE

## *MUREX TENUIVARICOSUS* DAUTZENBERG, AN OLDER NAME FOR *CHICOREUS (SIRATUS) CARIOCA* VOKES (*MUREX CALCAR* KIENER *NON* SOWERBY)

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Having just recently renamed the homonym *Murex calcar* Kiener, 1843, *non* J. de C. Sowerby, 1823, *nec* Sacchi, 1835, the writer was completely shocked and not a little dismayed to discover that an older name had been proposed for this homonym by Philippe Dautzenberg in 1927. This new name was buried in a discussion of *Trophon (Pagodula) vaginatus* (Cristofori and Jan, 1832), of which *Murex calcar* Sacchi is a synonym. The new name, *Murex tenuivaricosus,* was proposed in the *Résultats des Campagnes Scientifiques du Prince de Monaco,* Fasc. 72, p. 94, and to the writer's knowledge has been totally overlooked by subsequent workers.

VOKES, EMILY H., 1968, *Chicoreus (Siratus) carioca,* new name for *Murex calcar* Kiener: Tulane Stud. Geol., v. 6, no. 1 (July 31, 1968), p. 39-40.

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# REVIEW

## THE HEART OF THE EARTH

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THE HEART OF THE EARTH, by O. M. Phillips. Published by Freeman, Cooper & Co., San Francisco, 1968, 236 pp., 73 figs., 2 appendices, a short bibliography, and index, $4.50

A book which appears at first glance to be just another "popular" approach to generalized knowledge concerning the interior of the earth . . . and turns out, even in a quick perusal, to be a very well-written and thorough geophysical search into the nature of the earth, how we know, and how accurate are the details. Divided into chapters on gravitation and the figure of the earth, the mass of the earth, earthquakes and seismic waves, volcanoes and inner temperatures, continental drift, and the earth's magnetic field, the facts uncovered in the search are progressively and intelligently introduced and tend to build a significant mass of evidence supporting the author's conclusions.

Geophysics without mathematics is an impossibility but the author has done an admirable job of holding the use of it to a minimum. Some of this has been achieved through the use of excellent diagrams (such as the three-dimensional "pictures" of successive stages of deformation of blocks of material due to passage of shear and compressional waves), some achieved by using words and phrases in equations so that the reader does not recognize it as mathematics, but mostly this results from the extremely frequent use of graphs to illustrate relationships rather than using mathematical formulae.

The final result of this approach is a beautifully written book by a man who is an artist with words, dealing with a quite difficult subject in an almost never condescending way, and yet being always intelligible to technically educated but non-geophysical readers. An excellent book for a general seminar on the nature of the earth including students, advanced undergraduates and graduates, from a half-dozen disciplines . . . which is where I plan to use it.

# A PLIOCENE MOLLUSCAN FAUNULE FROM TRINIDAD

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## Introduction

A report on Miocene and Pliocene mollusks from Trinidad (Jung, 1969) was completed when the writer undertook the identification of a small molluscan fauna from the Talparo Formation of Trinidad. This faunule had been collected by Karl Rohr (KR 13900) in the Mahaica District, which is situated on the northern slope of the Central Range of Trinidad, about 14 kilometers south of Arima. The fossiliferous outcrop had been found in a branch stream of the Cunupia River (coordinates: N 360′ 060 links, E 445′ 260 links). The exact geographic location of this outcrop is shown on a detailed map to be published by H. G. Kugler, Basel. According to Kugler (1961, map) this locality (= Naturhistorisches Museum Basel locality 10437), which is situated on the axis of the Mahaica anticline, belongs to the Caparo Clay Member of the Talparo Formation and has been selected as the type locality for mollusks of the Caparo Clay Member (Kugler MS).

According to Rohr (private report, 1937) the faunule came from a 15 feet thick lens of limonitic or glauconitic conglomeratic sandstone situated in the uppermost part of the Caparo Clay Member. The lithological and faunistical aspects of the faunule are strikingly similar to those of the fauna from the Matura shell bed. Their correlation, therefore, seems highly probable.

## Fauna

All the specimens contained in this faunule are strongly rolled, a feature observed frequently in material from the Matura shell bed as well. A number of forms cannot be identified specifically, because they are represented by small fragments only. The following 22 forms have been recognized from NHMB locality 10437:

Pelecypoda:

- *Barbatia* (*Obliquarca*) cf. *B. cancellaria* (Lamarck)
- *Noetia* (*Eontia*) *centrota* (Guppy)
- *Brachydontes* species
- *Ostrea* species
- *Aequipecten* (*Plagioctenium*) species
- *Anomia simplex* d'Orbigny
- *Crassinella* species
- *Trachycardium* (*Dallocardia*) *sanctidavidis* (Maury)
- *Semele purpurascens* (Gmelin)
- *Strigilla* (*Pisostrigilla*) *pisiformis* (Linné)
- *Donax* cf. *D. striatus* Linné
- *Juliacorbula aequivalvis* (Philippi)

Gastropoda:

- *Diodora cayenensis* (Lamarck)
- *Neritina* species
- *Turritella* (*Broderiptella*) aff. *T. planigyrata* Guppy
- *Cerithiopsis* species
- *Modulus* species
- *Triphora* species
- *Natica* (*Naticarius*) aff. *N. canrena* (Linné)
- *Crucibulum* (*Crucibulum*) *piliferum* Guppy
- *Olivella* (*Niteoliva*) cf. *O. verreauxii* (Ducros)
- *Prunum* (*Prunum*) aff. *P. dallianum* (Maury)

Of these 22 forms there are 12 species occurring in the Matura shell bed as well. The remaining 10 forms belong to genera represented also at Matura. But unfortunately they are not determinable specifically, although it is probable that they are conspecific with those found at Matura. *Barbatia* (*Obliquarca*) cf. *B. cancellaria* (Lamarck) and *Prunum* (*Prunum*) aff. *P. dallianum* (Maury) are the only species not recorded from Matura. In addition the form listed above as *Modulus* species is represented by a single, fragmentary, worn specimen, and is not conspecific with *M. carchedonius* (Lamarck) recorded from the Matura shell bed (Jung, 1969, p. 452).

## Genus Barbatia Gray

Gray, 1842, Synopsis of the contents of the British Museum, ed. 44, p. 81.

Type species (by subsequent designation, Gray, 1847, Proc. Zool. Soc. London, pt. 15, p. 197), *Arca barbata* Linné. Recent, Mediterranean Sea.

### Subgenus OBLIQUARCA Sacco

Sacco, 1898, I Molluschi dei terreni terziarii del Piemonte e della Liguria, pt. 26, p. 16.

Type species (by original designation), *Arca modioliformis* Deshayes. Eocene, Paris Basin.

### BARBATIA (OBLIQUARCA) cf. B. CANCELLARIA (Lamarck)

Plate 1, figs. 1,2

This species is represented by a few incomplete and strongly worn shells. The lack of reduced denticles at the center of the hinge may be due to erosion. The ligament is narrow and restricted to the area behind the beaks. The external sculpture is hardly recognizable, but consists of numerous radials.

*B. cancellaria* sometimes occurs abundantly in the Recent Caribbean fauna (Abbott, 1958, p. 110). It is usually assigned to the subgenus *Barbatia.* Sacco originally included only modioliform species in his subgenus *Obliquarca,* but Woodring (1925, pp. 38-40) described three species from the Bowden Formation of Jamaica, two of which are not modioliform at all. According to Reinhart (1935, p. 25) *Obliquarca* is distinguished from *Barbatia s. str.* by having its ligament entirely behind the umbones. As stated by Olsson (1961, p. 81) "the ligament covers only the posterior part of the cardinal area" in *B. cancellaria.*

### Genus NOETIA Gray

Gray, 1857, Ann. Mag. Nat. Hist., (ser. 2) vol. 19, p. 371.

Type species (by monotypy), *Noetia triangularis* Gray (= *Arca reversa* G. B. Sowerby I). Recent, eastern Pacific.

### Subgenus EONTIA MacNeil

MacNeil, 1938, U. S. Geol. Survey, Prof. Paper 189-A, p. 11.

Type species (by original designation), *Arca ponderosa* Say. Recent, east coast of the United States.

### NOETIA (EONTIA) CENTROTA (Guppy)

Plate 1, figs. 3,4

1867 *Arca centrota* Guppy, Proc. Sci. Assoc. Trinidad, pt. 3, p. 175. (Reprint, Harris, 1921, Bulls. Amer. Paleontology, vol. 8, no. 35, p. 54.)
1938 *Eontia centrota* (Guppy), MacNeil, U. S. Geol. Survey, Prof. Paper 189-A, p. 12, pl. 1, figs. 11,12. Lectotype figured. For additional citations see this publication.
1942 *Eontia centrota* (Guppy), Rutsch, Verh. Naturf. Ges. Basel, vol. 54, p. 110.
*Lectotype*: USNM 496508.
*Type locality*: Matura, Trinidad.

Although most abundant at its type locality, this species is represented only by a few valves in the faunule under study. They do not reach the size of valves from the Matura shell bed.

*N. centrota* has not been found outside Trinidad yet. It has been collected from deposits of late Miocene to Pliocene age.

→

### EXPLANATION OF PLATE 1

Figure — Page

All the specimens are from Naturhistorisches Museum Basel locality 10437.

1,2 *Barbatia* (*Obliquarca*) cf. *B. cancellaria* (Lamarck) (X 2) ..... 86
Length 22.3 mm; height 12.8 mm. Nat. hist. Mus. Basel No. G 14061.

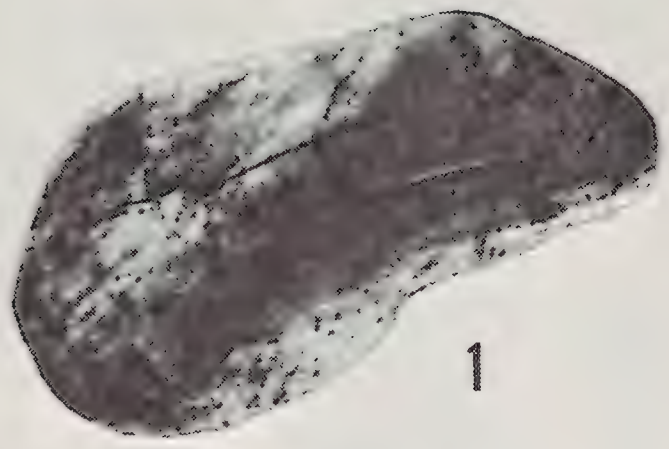
3,4 *Noetia* (*Eontia*) *centrota* (Guppy) (X 2) ..... 86
Length 22.2 mm; height 14.3 mm. Nat. hist. Mus. Basel No. G 14062.

5 *Juliacorbula aequivalvis* (Philippi) (X 5) ..... 88
Length 6.7 mm; height 5.1 mm. Nat. hist. Mus. Basel No. G 14063.

6 *Crucibulum* (*Crucibulum*) *piliferum* Guppy (X 2) ..... 88
Maximum diameter 16.7 mm. Nat. hist. Mus. Basel No. H. 15402.

7 *Turritella* (*Broderiptella*) aff. *T. planigyrata* Guppy (X 2) ..... 88
Height 32.0 mm; maximum diameter 14.2 mm. Nat. hist. Mus. Basel No. H. 15401.

8 *Prunum* (*Prunum*) aff. *P. dallianum* (Maury) (X 2) ..... 88
Height 21.2 mm; width 17.2 mm. Nat. hist. Mus. Basel No. H. 15403.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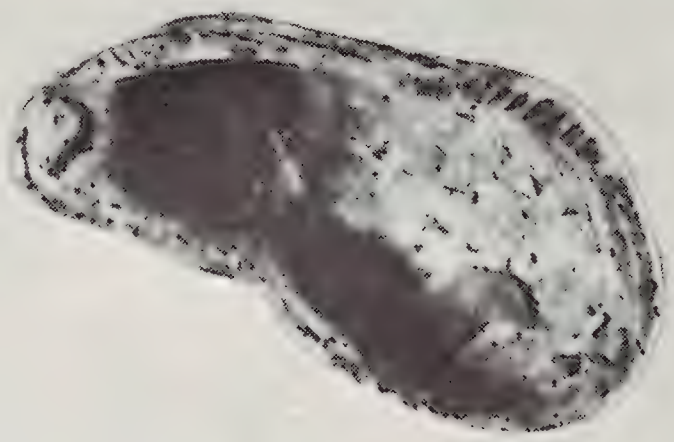
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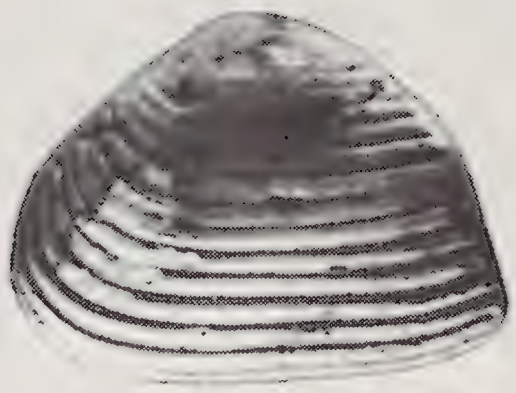
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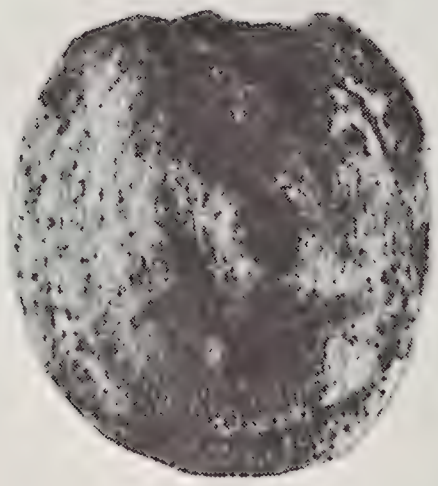
6

7

8

PLATE 1

### Genus JULIACORBULA Olsson and Harbison

Olsson and Harbison, 1953, Acad. Nat. Sci. Philadelphia, Monograph no. 8, p. 148.

Type species (by original designation), *Corbula cubaniana* d'Orbigny (= *Corbula knoxiana* C. B. Adams = *Corbula aequivalvis* Philippi). Recent, Florida and Caribbean.

#### JULIACORBULA AEQUIVALVIS (Philippi)

Plate 1, fig. 5

1836 *Corbula aequivalvis* Philippi, Archiv für Naturg., vol. 2, p. 227, pl. 7, fig. 4.
1964 *Corbula* (*Juliacorbula*) *aequivalvis* Philippi, Weisbord, Bulls. Amer. Paleontology, vol. 45, no. 204, p. 393, pl. 57, figs. 3-6. For further citation see this publication.

*J. aequivalvis* occurs abundantly in the Matura shell bed, but is represented in the faunule under study by a few valves only. At Matura the specimens vary in shape from subquadrate to elongate. The same variability is shown by the Mahaica valves. Related forms are discussed elsewhere (Jung, 1969, p. 410).

### Genus TURRITELLA Lamarck

Lamarck, 1799, Mém. Soc. Hist. Nat. Paris, p. 74.

Type species (by monotypy), *Turbo terebra* Linné. Recent, western Pacific.

#### Subgenus BRODERIPTELLA Olsson

Olsson, 1964, Neogene mollusks from northwestern Ecuador, p. 188. Paleont. Research Inst., Ithaca, N. Y.

Type species (by original designation), *Turritella broderipiana* d'Orbigny. Recent, eastern Pacific.

#### TURRITELLA (BRODERIPTELLA) aff. T. PLANIGYRATA Guppy

Plate 1, fig. 7

This species is fairly frequent at Matura and its affinities to *T. planigyrata* Guppy 1867, pp. 156,169) and to the Recent Caribbean *T. variegata* (Linné) have been described by the writer (Jung, 1969, p. 439). The Mahaica faunule contains only four fragmentary specimens. They are indistinguishable from Matura specimens. The figured shell is somewhat compressed laterally.

### Genus CRUCIBULUM Schumacher

Schumacher, 1817, Essai d'un nouveau système des habitations des vers testacés, pp. 56,182.

Type species (by subsequent designation, Burch, 1946, Min. Conchological Club Southern California, No. 56, p. 19), *Crucibulum planum* Schumacher (= *Patella auricula* Gmelin). Recent, Florida and West Indies.

#### Subgenus CRUCIBULUM *s. str.*

#### CRUCIBULUM (CRUCIBULUM) PILIFERUM Guppy

Plate 1, fig. 6

1867 *Crucibulum piliferum* Guppy, Proc. Sci. Assoc. Trinidad, pt. 3, pp. 160,172. (Reprint, Harris, 1921, Bulls. Amer. Paleontology, vol. 8, no. 35, pp. 39,51.)

This species is represented by five specimens. Their spines are but poorly developed, or even absent on account of erosion. Unusually flat shells such as occur at Matura are missing.

### Genus PRUNUM Herrmannsen

Herrmannsen, 1852, Indicis generum malacozoorum. Supplementa et corrigenda, p. 113.

Type species (by monotypy), *Voluta prunum* Gmelin. Recent, West Indies.

#### Subgenus PRUNUM *s. str.*

#### PRUNUM (PRUNUM) aff. P. DALLIANUM (Maury)

Plate 1, fig. 8

A single shell is available. It is damaged and somewhat worn, but its outer lip is preserved. *P. dallianum* (Maury) (1912, p. 67, pl. 10, figs. 5, 6) was originally described from the Courbaril beds (Pliocene) of the Pitch Lake area, Trinidad. Comparison with topotypes shows that the Mahaica specimen is stouter. The upper part of its body whorl is more inflated, the lower part more constricted, and its outer lip is more strongly arched. The columellar folds are heavier than in *P. dallianum.*

A few specimens from Matura have questionably been identified as *P. dallianum* (Jung, 1969, p. 533). They are more slender than the Mahaica shell.

## CONCLUSIONS

The Talparo Formation consists of a rather heterogeneous sequence of deposits.

Its most prominent features are the large bodies of practically unconsolidated sands in predominantly clayey sediments. Occasional lenses yielding a fauna like the one discussed in this paper represent a marine near-shore environment with slight brackish water influence. The presence of *Cyanocyclas* or *Anadara* (*Larkinia*) *patricia* point to strong brackish water influence. Lignitic beds associated with sands containing possible traces of decayed mangrove roots suggest a coast swamp environment, whereas fossils like *Hyria* and *Hemisinus* prove the presence of fresh water.

The Talparo Formation represents part of the sediments filling the basin situated between the present Central and Northern Ranges (Caroni Syncline). The composition of the sediments as outlined above points to an unsteady environment with fluctuations of the sea. Kugler (1961, map) subdivided the Talparo Formation into seven members. The molluscan fauna recorded herein has been collected from a lens in the Caparo Clay Member, in the middle member of the formation. The Matura beds are considered by Kugler (1961, map) to be the top member of the Talparo Formation and the last marine transgression (Kugler, 1953, p.55).

According to field observations the marine lens of the Mahaica District represents a lens within the Caparo Clay Member, whereas the Matura beds can hardly be defined as a member due to lack of stratigraphic relations. It is suggested that the Matura beds be considered as a marine lens within the the Caparo Clay Member of the Talparo Formation on account of the striking faunistic and lithological similarity with the fauna recorded herein.

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July 16, 1969

# RECENT BOOK

CYCLIC SEDIMENTATION, by P. McL. D. Duff, A. Hallam and E. K. Walton. Published by Elsevier Publishing Company, Amsterdam, London and New York, 1967, x + 280 pp., $23.50

*Cyclic Sedimentation,* the tenth volume in the *Developments in Sedimentology* series, is the first attempt at comprehensive treatment of this subject. Seven central chapters describe and evaluate the evidence of cyclic sedimentation from continental, transitional and marine environments, followed by chapters on flysch and turbidity currents and on faunal changes within sedimentary cycles. In the general conclusions, the authors state that cyclicity is inherent in sedimentation and that it is unrealistic to look for a single all-embracing mechanism. They conclude with discussion of sedimentary, tectonic, eustatic and climatic controls on cyclic development.

(*Continued from page 74*)

## Conclusion

As Cati *et al.* (1968) point out, the scattered Mediterranean Plio-Pleistocene sections still afford a variety of correlation and zonation schemes based on planktonic foraminifera. They imply caution in the use of *G. crassaformis* s.l. in zonation, declining use of its possible subspecies *G. crassula, G. aemiliana, G. crotonensis,* and *G. crassacrotonensis* because this lineage ". . . with its many taxonomic problems . . ." is still being studied. This group of twenty-one authors agreed unanimously on a single zonation for the Mediterranean Miocene, but could agree on no fewer than three alternate zonations for the Pliocene. Pending further knowledge regarding species ranges in both regions, it is the writer's belief that in the Gulf Coast, the ranges of these and other species must be more firmly established before correlation with Italy can be reliably assumed.

## Acknowledgments

The writer thanks W. H. Akers for reviewing the typescript and Chevron Oil Company for permission to publish.

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July 16, 1969

# PALEONTOLOGICAL NOTE

## ADDENDUM TO CORRECTION OF THE TYPE SPECIES OF *GLOBULINA* D'ORBIGNY

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*CHEVRON OIL COMPANY, NEW ORLEANS*
and
HUBERT C. SKINNER
*TULANE UNIVERSITY*

The writers regret that acknowledgment of the contribution of W. H. Akers of Chevron Oil Company, New Orleans, who provided the specimen of *Globulina caribaea* d'Orbigny illustrated in the original paper (Poag and Skinner, 1968, p. 128), was inadvertently omitted in publication. Through the kindness of Mr. Akers the figured specimen was obtained and donated to the Tulane Geological Collections (TGC 12-1).

POAG, C. WYLIE, and HUBERT C. SKINNER, 1968, Correction of the type species of *Globulina* d'Orbigny: Tulane Stud. Geol., v. 6, no. 3 (November 22, 1968), pp. 127-128.

# RECENT BOOKS

DICTIONARY OF APPLIED GEOLOGY: Mining and Civil Engineering, edited by A. Nelson and K. D. Nelson. Published by Philosophical Library Inc., New York, 1967, vii + 421 pp., $17.50

Intended primarily for students and mining and civil engineers, this dictionary lists minerals, gemstones, rock types and terminology relating to raw fuels, coals, petroleum and natural gas, building materials and rock structures.

OIL PROPERTY VALUATION, by Richard V. Hughes. Published by John Wiley & Sons, Inc., New York, London and Sydney, 1967, xi + 313 pp., $11.50

This book is designed to acquaint the reader with the many factors which determine the present-worth of oil properties. It is intended as a textbook and a reference work for those engaged professionally in the many aspects of oil property valuation.

DEBATE ABOUT THE EARTH: Approach to Geophysics through Analysis of Continental Drift, by H. Takeuchi, S. Uyeda and H. Kanamori. Published by Freeman, Cooper & Co., San Francisco, 1967, 253 pp., $4.50

The theory of continental drift is reviewed in the light of modern knowledge and techniques of geophysics and geology, demonstrating how various fields of earth science, such as paleontology, rock magnetism and oceanography, have important interconnections when we consider a fundamental, engrossing problem such as continental drift.

DIAGENESIS IN SEDIMENTS, edited by Gunnar Larsen and George V. Chilingar. Published by Elsevier Publishing Company, Amsterdam, London and New York, 1967, vi + 551 pp., $30.00

This, the eighth volume in the *Developments in Sedimentology* series, is an overall survey of diagenetic processes by a number of prominent specialists. It begins with a general outline of diagenesis processes followed by discussion of diagenetic evolution from the syndiagenetic stage to anadiagensis and finally epidiagenesis. Succeeding chapters deal with diagenetic features related to the different types of sedimentary rocks and their constituents such as organic matter, and the subjects of coalification, sedimentary mineral deposits, subsurface waters and interstitial solutions.

INTRODUCTION TO GROUND-WATER HYDROLOGY, by Ralph C. Heath and Frank W. Trainer. Published by John Wiley & Sons, Inc., New York, London and Sydney, 1968, xii + 284 pp., $9.95

This book was written as a text-manual to meet the need for laboratory exercises in introductory courses in ground-water hydrology. Each chapter contains problems designed to illustrate fundamental principles and practical engineering problems encountered by hydrologists.

ULTRAMAFIC *and* RELATED ROCKS, edited by P. J. Wyllie. Published by John Wiley & Sons, Inc., New York, London and Sydney, 1967, xx + 464 pp., $22.50

This is the first detailed description of the ultramafic rocks. It includes 41 articles by 33 authors grouped into 12 chapters organized skillfully into a comprehensive and readable volume, forming a quite useful supplement to the general textbooks on petrology which cannot treat the origins of specific groups of rocks in detail.

GEOCHEMICAL PROSPECTING IN FENNOSCANDIA, edited by Aslak Kvalheim. Published by Interscience Publishers (John Wiley & Sons), New York, London and Sydney, 1967, viii + 350 pp., $15.00

The book begins with an outline of the geology and physiography of Finland, Norway and Sweden and a discussion of the soils of Fennoscandia. Part II, the main portion of the book, is comprised of 14 progress reports on different aspects of geochemical prospecting by various authors from Finland and the Scandinavian peninsula. Part III deals with equipment and analytical methods.

PETROGENESIS OF METAMORPHIC ROCKS, by H. G. F. Winkler. Second revised edition, published by Springer-Verlag New York Inc., 1967, x + 237 pp., $5.80 (soft cover)

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AMPHIBOLES, by W. G. Ernst. Published by Springer-Verlag New York Inc., 1968, x + 126 pp., $6.80

This is the first volume in *Minerals, Rocks and Inorganic Materials,* a new series of monographs intended to present recent research and results in the study of selected mineral groups beyond the scope of the mineralogy textbook, but at modest cost. In *Amphiboles,* Professor Ernst presents in historical perspective a review of crystal chemistry and classification of the amphiboles and summarizes the current knowledge of chemical variability and experimentally determined phase relationships in this group and attempts to correlate these features with natural occurrences.

THE PRECAMBRIAN, edited by Kalervo Rankama. Published by Interscience Publishers (John Wiley & Sons, Inc.), New York, London and Sydney, 1963-1968, vol. 1, xxiv + 279 pp., $9.95; vol. 2, vii + 454 pp., $16.50; vol. 3, vii + 325 pp., $17.50

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# TULANE STUDIES IN GEOLOGY AND PALEONTOLOGY

Volume 7, Numbers 3, 4 December 29, 1969

Number 3

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HAROLD E. VOKES
*TULANE UNIVERSITY*

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## I. Abstract

The genus *Miltha* H. & A. Adams, 1857, has been the subject of much misunderstanding and mis-interpretation, largely as a result of the rarity of the type species, "*Lucina*" *childrenae* Gray, in museum collections. Described from "Brazil" by Gray, the species was confused by Carpenter (1864) and following him, Dall (1901, 1903) with the species from Baja California subsequently named *Miltha xantusi* by Dall (1905). At the time of his monograph on "The Tertiary Faunas of Florida" Dall had seen no specimens of the type species and treated *Miltha* as a subgenus of *Phacoides* "Blainville," giving it an unjustifiably broad interpretation that was uncritically accepted by a number of subsequent authors. As a result fourteen species from the Tertiary of eastern North America have been referred to *Miltha*, only two of which, *M. chipolana* (Dall) and *M. caloosaensis* (Dall), are here accepted as correctly referred to that genus, with two others, *M. heracleus* (Dall) and *M. smithwoodwardi* (Maury) being placed in the synonymy of *M. chipolana.* The other ten species are here referred to *Armimiltha, Eomiltha, Plastomiltha* or *Saxolucina.*

*Miltha s.s.* includes species that, in the adult stages, differ in degree of inflation of the opposite valves; in the species here studied either valve may be inflated with no predominance of one over the other observed in any species. The valves have a fine concentric ornamentation with a weak and obscure radial ribbing. Anterior and posterior dorsal areas are defined by incised grooves; the posterior is well developed, but the anterior may be rather obscure. The lunule is small, confined to the right valve and more or less deeply impressed into the area immediately below the umbos. The adult hinge includes two cardinal teeth in each valve, the posterior right cardinal and the anterior left one are bifid, the others simple, more or less lamellar. There is no trace of lateral teeth in the adult hinge, but both anterior and posterior laterals are present in small, immature forms. These same forms also show a well developed escutcheon, a remnant of which persists in the adult valves as a flat, plate-like protrusion of the right valve that is partly broken away by the action of the enlarging fibrous portion of the ligament.

The interior of the valve bears ridges and grooves that reflect structures in the mantle area including the attachment area of the gill demibranchs, the trend of the large pallial blood vessel and, apparently, the presence of a "non-ridged fold" margining a region of "mantle gills" such as have been described in other lucinid genera by Allen (1958) and others. The anterior and posterior adductor scars show clear evidence that these muscles included both "striated" and "smooth" types of muscle fibers—as do other species of Lucinidae.

The two recent species of *Miltha, M. childrenae* and *M. xantusi* both occur in waters of 28 to 30 fathoms or more in depth, and both appear to prefer fine sandy types of bottom sediment.

The oldest species of *Miltha s.s.* appears to be *M. packi* (Dickerson) from the Domengine Formation, middle Eocene, of California. "*Phacoides*" *montensis* Cossmann is a possible ancestral type. No certain upper Eocene or Oligocene forms have yet been recognized, but the genus is present in the lower Miocene of California, Florida, and New Zealand, persisting to the Recent in tropical waters of the eastern Pacific and the western Atlantic Oceans.

Three species of *Miltha* are present in the Florida Neogene deposits: *M. chipolana* Dall, from the early Miocene Chipola Formation; *M. caloosaensis* Dall, from the upper Miocene Pinecrest beds, and the Pliocene Caloosahatchee Formation; and *M. carmenae*, new species, from the early Pleistocene "Unit A" beds from the region south and south east of Lake Okeechobee, Florida.

## II. Introduction

During a visit to the Pascagoula, Mississippi, station of the Bureau of Commercial Fisheries, U. S. Fish and Wildlife Service, Mrs. Gladys B. Reese, Fisheries Biologist, drew my attention to a collection of specimens of the rare and imperfectly understood *Miltha childrenae* (Gray) that had been dredged by the M/V *Oregon* off the northeastern coast of Brazil. Comparison of these specimens with the original descriptions and specimens in the Tulane University collections of the Florida Neogene species of *Miltha* indicated that there has been much

misunderstanding and published misinformation concerning the genus. The following observations are presented in an endeavor to give a more accurate knowledge of the genus and its North American western Atlantic species.

## III. Acknowledgments

The acumen of Mrs. Gladys B. Reese, Fisheries Biologist, who recognized that the Brazilian specimens of *Miltha childrenae* merited study and who called them to my attention is greatly appreciated. I am indebted also to Mr. Harvey R. Bullis, Jr., Base Director of the Pascagoula station, who permitted me to borrow them for comparison with the Florida specimens. Mr. and Mrs. Robert C. Hoerle of West Palm Beach, Florida, gave free access to their extensive collections of fossils from southern Florida and donated a number of specimens to the Tulane University collections; their continuing kindness and cooperation is much appreciated.

The care with which the members of the editorial committee reviewed the manuscript is most sincerely appreciated. Dr. Keen also made available data concerning specimens of *Miltha xantusi* (Dall) in the Stanford University collections, and Dr. Hertlein furnished information on references not available to me.

This study has been part of a program for the investigation of Tertiary and Recent species of Mollusca from the western Atlantic region conducted by my wife and I under the auspices of National Science Foundation Grant GB-6048. Much of the material upon which it is based was collected under the aegis of this grant and the financial assistance of the foundation is gratefully acknowledged.

## IV. Genus Miltha H. and A. Adams, 1857

1857, *Miltha* H. and A. Adams, Genera Rec. Moll., vol. 2, p. 468.
1876, *Milthea* Meek, Rept. U. S. Geol. Surv. Territories (Hayden), vol. 9, p. 130, 131 [as "*Milthea* H. and A. Adams"].
1931, *Milthoidea* Marwick, New Zealand Geol. Surv., Paleont. Bull. 13, p. 70.
1938, *Miltheoidea* Marwick, Chavan, Journ. de Conchyl., vol. 82, p. 64.

Type species, by monotypy, [*Lucina* (*Miltha*)] "*Childreni* Gray" [= *L. childrenae* Gray, 1824]: Recent, Atlantic Ocean off Brazil.

*Miltha* was proposed as a subgenus of *Lucina* Bruguière with the original diagnosis: "Shell inequivalve, with the surface of the valves nearly smooth. Hinge with the lateral teeth obsolete."

Examination of the original description and illustrations of *Miltha neozelanica* Marshall and Murdock (1921, p. 78, pl. 16, pl. 17, fig. 1) leave no doubt but that this form is a typical *Miltha* and that *Milthoidea* Marwick, 1931, of which this species is type, by original designation, is a synonym of *Miltha* as previously noted by Stewart (1930, p. 191) and by Chavan (1938, p. 64).

### A. *History of Previous Interpretation of the Genus*

*Distribution of type species.*—Although the type species was described as early as 1824 and subsequently well figured (the hinge and interior of the right valve by Sowerby [1826, Genera of Shells, Pt. 27, *Lucina*, fig. 2], and the hinge of the left valve and exterior of the right by Reeve [1850, Conch. Icon., "*Lucina*," sp. 12]), the rarity of the type species has led to much misunderstanding, not only of its provenance and distribution, but also of its essential characters. This misunderstanding apparently was initiated by Carpenter who, in commenting upon a collection of shells made by Mr. J. Xantus at Cape San Lucas, Baja California, lists (1864, p. 620) *Miltha Childreni*, adding: "A few fresh specimens correct the habitat 'Brazil,' previously assigned to this extremely rare and remarkable shell, . . ." Earlier (p. 522), in noting that a price of £10 10s. had been listed for two specimens of this species in the sale of Tankerville collection, he stated: "There is no authority for the statement that it came from Brazil. The Br. Mus. specimens are from the 'Mus. Cracherode,' and are probably West Coast. The only known locality is Cape St. Lucas."

Carpenter's conclusions were accepted by subsequent authors, especially Dall: (1901, p. 812) " . . . the locality, Brazil, given in the Conchologia Iconica, is erroneous."; (1903, p. 1377) " . . . living in the Gulf of California." Later, upon receiving a specimen of the true *childrenae* collected at Pernambuco, Brazil, Dall (1905, p. 110) acknowledged that his above locality cita-

tions were in error and (p. 111) named the Gulf of California species *Phacoides* (*Miltha*) *xantusi*. But Dall's 1905 paper seems to have been rather generally overlooked and among others we find Maury stating in the discussion of her "*Phacoides* (*Miltha*)" *smithwoodwardi* (1917, p. 369): "This species is apparently the ancestor of . . . *M. childreni* Gray . . . living in the Gulf of California." As late as 1953, Olsson and Harbison, after correctly citing the species as from Brazil (p. 88), refer to it, on p. 89 as "the Recent *Miltha childreni* from the Gulf of California."

*Species previously included in Miltha.*— The misunderstanding concerning the essential characters of the species to be referred to *Miltha* appears to stem primarily from the work of Dall, who in 1903 assigned it to a position as a subgenus of *Phacoides* "Blainville" typified by *Lucina jamaicensis* Lamarck, a species with the anterior cardinal obsolete and the posterior reduced, but with strong laterals. He recognized three species groups in his "subgenus" *Miltha* (1903, p. 1374):

"A. Species of which the surface sculpture is characterized by concentric lamellation like *P.* (*M.*) *disciformis* and *hillsboroënsis* of Heilprin.

"B. Species compressed, high, with fine concentric striation, like *P.* (*M.*) *Childreni* Gray and *caloosaënsis* Dall.

"C. Species with sculpture similar to the last but more convex and elongated with a somewhat sinuous basal profile, like *P.* (*M.*) *pandatus* Conrad and *Voorhoevii* [*sic*] Deshayes."

Dall listed or discussed 12 American Tertiary and Recent species that he referred to *Phacoides* (*Miltha*). His arrangement was followed by Maury (1917, pp. 368-9) and by Gardner (1926, pp. 111-2) each of whom added two new species. In terms of present interpretation the following assignments may be made of these species:

1. Forms referred to group "A" of Dall:

*Lucina disciformis* Heilprin (1886, Trans. Wagner Free Inst. Sci., vol. 1, p. 94, pl. 11, fig. 28) = type of *Armimiltha* Olsson and Harbison (1953, p. 83).

*Lucina hillsboroensis* Heilprin (1886, *ibid.*, p. 117, pl. 16, fig. 62) = *Armimiltha.*

*Cyclas claibornensis* Conrad (1865, Amer. Jour. Conch., vol. 6, p. 146) = type of *Plastomiltha* Stewart (1930, p. 191).

*Phacoides* (*Miltha*) *riocanensis* Maury (1917, Bulls. Amer. Paleontology, vol. 5, p. 369, pl. 61, fig. 7) = *Armimiltha.*

*Phacoides* (*Miltha*) *heilprini* Gardner (1926, U. S. Geol. Surv., Prof. Paper 142C, p. 112, pl. 19, Figs. 7, 8) = *Armimiltha.*

2. Forms referred to group "B" of Dall:

These are for the most part the species referred to *Miltha s.s.* and discussed in the present paper. It is to be remembered, however, that as noted above, Dall misapplied the name "*Childreni* Gray" to the Gulf of California species now know as *Miltha xantusi Dall.* In addition to *childrenae*, the following named species have been referred to this group: *caloosaensis* (Dall, 1898), *chipolana* (Dall, 1903), *heracleus* (Dall, 1903), and *smithwoodwardi* (Maury, 1917). The latter two are here held to be synonyms of *chipolana.*

In addition to the species listed, Dall added *Lucina claytonia* Harris (1896, Bulls. Amer. Paleontology, vol. 1, p. 183, pl. 16, figs. 10, 10a), stating that it "is also a *Miltha* belonging to group B of the section." This species was tentatively referred by Stewart (1930, p. 184) to *Saxolucina* (*Codalucina*) and by Chavan (1938, p. 70) to *Saxolucina.*

3. Forms referred to group "C" of Dall:

*Lucina pandata* Conrad (1833, Amer. Jour. Sci., vol. 23, p. 343) = *Eomiltha* Cossmann, 1911.

*Phacoides* (*Miltha*) *ocalanus* Dall (1903, p. 1375, pl. 50, fig. 14). The position of this species, known only from internal casts, is uncertain. As noted by Dall the cast has the form of *pandata* [= *Eomiltha*], but the elongate structure, interpreted by Dall as the posterior adductor scar, is entirely unlike anything to be observed in *pandata* or other species of *Eomiltha.* The same structure is well shown in Harris' (1951, pl. 39, fig. 7) figure of a specimen from Reddick, Florida, and it cannot, therefore, be interpreted as of pathologic origin. Specimens in the Tulane collection are also similar in this respect, but one seems to show a small, divided posterior adductor scar, similar to those found in *Eomiltha,* occupying the ventral end of the impressed

area. This latter shell, however, appears to have had an edentulous hinge and may well represent a species of *Pseudomiltha*.

*Phacoides* (*Miltha*) *xustris* Gardner (1926, U. S. Geol. Surv. Prof. Pap. 142C, p. 112, pl. 20, figs. 1, 2) = *Eomiltha* Cossmann, 1911.

4. Species tentatively referred to *Miltha* by Dall without assignment to one of his "groups":

"*Dosinia* (later *Lucina*) *gyrata*" Gabb, 1865, (Palaeontology California, vol. 1, p. 168, pl. 23, fig. 148) has been referred to *Eomiltha* by Stewart (1930, p. 192, pl. 12, fig. 11).

*Lucina subobliqua* Say (1824, Jour. Acad. Nat. Sci. Phila., vol. 4, p. 147). According to Dall (1903, p. 1378) this species "is still unfigured and I have not seen specimens. It would appear to be a *Miltha* from the description, though only four-fifths of an inch in length, and was obtained from the Miocene of Maryland, probably in St. Mary's County." This species appears not to have been reported since its original description, and cannot be given any definite generic assignment at this time.

The Recent species from the Mozambique Channel, *Lucina voorhoevei* Deshayes (1857, Jour. de Conchyl., vol. 6, p. 106, pl. 2, fig. 1), mentioned by Dall as a species of his "group C" has been referred to *Eomiltha* by Stewart (1930, p. 190) and Chavan (1938, p. 93, as "*voorhoovei*").

The general absence in American collections of specimens of the Recent species of *Miltha* and the fact that Dall in his great monograph on the Tertiary Faunas included under that name forms that are today referred to five different lucinid genera rather clearly explains the general lack of appreciation of those characters that serve to delimit the genus.

Furthermore, it is clear from statements made by Dall that he had not seen the original descriptions of Gray. Thus, in 1901 (p. 806), he states: "The type is *Lucina childreni* Gray, 1825, as *Tellina*.", and in 1903 his first entry in the synonymy of his "*Phacoides* (*Miltha*) *Childreni* Gray" is: "*Tellina Childreni* Gray, Ann. Phil., xxv., p. 136, 1824; Zool. Journ., i, p. 221, 1825." In both entries, the dates of which were reversed by Dall following an error first perpetrated by Sowerby, the species was referred to *Lucina*, and in both it was given the feminine termination, "*childrenae*." It was not until 1828 that it was referred to *Tellina* by Wood in the "Index Testaceologicus."

## B. *Characters of Genus* Miltha

*Valve inflation.*—Perhaps the most striking result of this broad interpretation of the genus has been a failure to realize the significance of the differing degree of inflation of the two valves as a character of generic importance. Yet it was this feature, and especially the fact that of the two specimens available in the Tankerville collection one had an inflated right and the other an inflated left valve, that was the basis upon which Gray first defined the type species (see page 116). An examination (Table 1) of 768 valves of four species from the Western Atlantic region[1] indicates that in *Miltha*, unlike other bivalvian genera with differing inflation of the two valves, either

[1] No specimens of *Miltha iheringiana* Doello-Jurado from the Tertiary Entrerrienne Formation of Entre Rios, Argentina, have been available. See: Doello-Jurado, 1919, *Physis*, Rev. Soc. Arg. Sci. Nat., vol. 4, p. 558.

| Species | Left Valves "flat" | Left Valves "inflated" | Right Valves "flat" | Right Valves "inflated" | Total |
|---|---|---|---|---|---|
| *childrenae* | 0 | 1 (= 1) | 4 | 4 (= 8) | 9 |
| *carmenae* | 47 | 27 (= 74) | 46 | 49 (= 95) | 169 |
| *caloosaensis* | 89 | 101 (= 190) | 118 | 85 (= 203) | 393 |
| *chipolana* | 60 | 45 (= 105) | 56 | 36 (= 92) | 197 |
| | 196 | 174 (= 370) | 224 | 174 (= 398) | 768 |

Table 1: Tabulation of the distribution of 420 "flat" and 348 "inflated" adult valves of species of *Miltha s.s.* examined during this study. The 9 valves of *M. childrenae* are from the collections of the U. S. Fish and Wildlife Service. Of the others, 166 are in the collections of Mr. and Mrs. R. C. Hoerle, West Palm Beach, Florida, and 593 are in the Tulane University collection.

valve may be more inflated than its opposite. The development of differing degree of inflation is a progressive feature in the ontogeny of the individual. Small valves of immature individuals are almost equally inflated and, in general, it is only after they have attained a height of about 25 mm that differentiation can be observed. Of the 768 larger valves available for this study 53% of the left and 56% of the right, or a total of 55% of all specimens, were of the less inflated type, a feature suggesting that the more inflated forms are less resistant to crushing or breakage than are the relatively flatter ones.

In all species the more inflated valve is slightly larger than the less inflated, which fits within it with a slightly beveled edge permitting tighter closure.

*Ornamentation.*—The surface in both valves is ornamented primarily by low, round-topped concentric growth lamellae. These are usually stronger near the margins than on the central part of the valve and and often become sufficiently strong on the anterior and posterior dorsal areas to give them a somewhat rugose appearance. In addition to this concentric ornament there is a weak radial ribbing that is usually visible only under strongly oblique lighting (see pl. 1, figs. 1-4). Individual ribs are low and round-topped, variable in width on different parts of the shell, being usually more abundant and narrower toward the umbonal region, becoming wider ventrally, apparently mainly by the dying out of the small groove-like interspaces between them. These ribs are probably most strongly developed —though always very weak—on the valves of *Miltha childrenae* and weakest on those of *M. carmenae.* In both of these species the individual ribs tend to be relatively wider than they are on the valves of *M. chipolana* and *M. caloosaensis.*

A second form of radial ornamentation consists of small, sub-parallel to anastomosing, microscopic grooves (pl. 1, fig. 4, insert). These are best developed in the interspaces between the concentric lamellae and may be an expression of the arrangement of the prisms in the upper shell layer.

Finally, there is also a series of minute raised threads that have a variable but generally tangential trend (pl. 1, figs. 5, 6). These are usually best seen toward the lateral margins of the valves, but occasional remnants may be observed on all parts of the valve surface (see pl. 1, figs. 1 and 2 —to the right of the center of each figure) and presumably would be universally present on completely unworn valves.

The most notable feature of the valve ornamentation is the development of anterior and posterior dorsal areas that are set off from the rest of the surface by grooves radiating from the umbo. The posterior area, always considerably larger and more strongly developed than the anterior, is usually said to bear in its median area a longitudinal sulcus of variable strength that divides it into two more or less equal parts. Examination of well preserved specimens suggests that the surface would better be described as having a rather strong rounded rib on the antero-ventral segment of the area, separated from the main valve surface by the strong sulcus that defines the inner margin of the area. The crest of this rib is equal to the height of the adjacent valve surface, while the portion dorsal to it is depressed below that level. The strength of the so-called "median sulcus" is a factor of the degree of roundness of the rib. If it is well rounded so that the postero-dorsal side is steep, a "sulcus" appears to be present, but if the postero-dorsal slope is broad and gradual no delimiting "sulcus" can be observed (compare figs. 1

→

PLATE 1

Portions of the surfaces of specimens of *Miltha* photographed under strong oblique lighting to emphasize minor features of the valve ornamentation. All magnifications are approximately four diameters except fig. 4 insert, which is fourteen diameters. Figures 1-4 are of median areas of the valve surface to show variations in the radial ribbing; figures 5 and 6 are near the ventral margin to show the obliquely tangential thread-like ridges. Figs. 1 and 6, *Miltha* (*Miltha*) *childrenae;* figs. 2 and 5, *M.* (*M.*) *carmenae;* fig. 3, *M.* (*M.*) *chipolana;* fig. 4, *M.* (*M.*) *caloosaensis.*

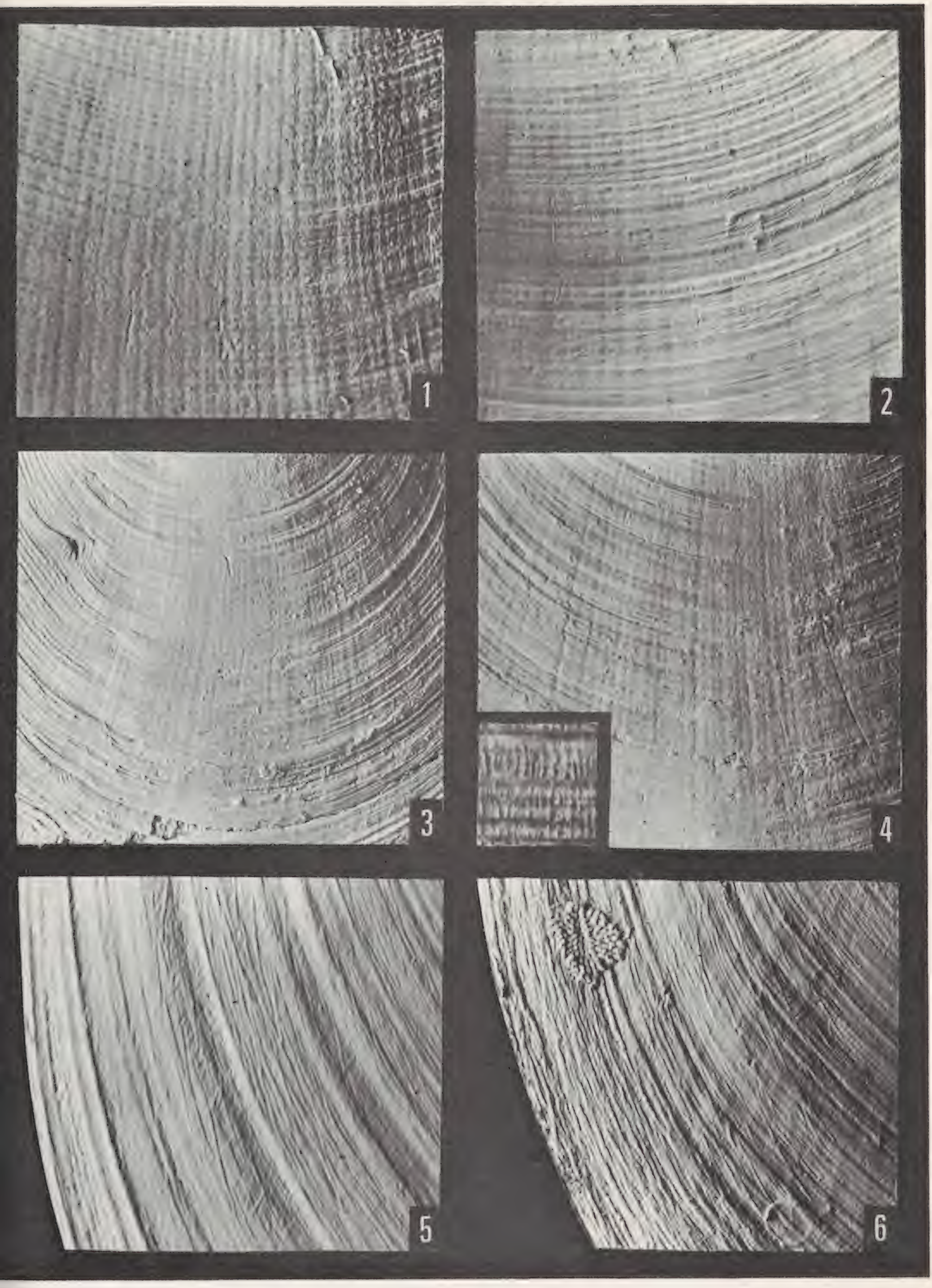


PLATE 1

and 4, pl. 4). In none of the specimens studied has it been possible to observe a true median groove on the area.

The strength of this rib is variable and not a character of value for specific discimination within the genus. It is, perhaps, most consistently narrow and steep-sided on *M. caloosaensis*, but even in this species there are numerous specimens with a sloping postero-dorsal side. In contrast, the rib is weak, almost absent, on most specimens of *M. carmenae* but is narrow and high on one individual valve.

The anterior dorsal area is always small and narrowly elongate, usually not strongly delimited from the main surface of the valve. It is best developed on *M. caloosaensis*, with its ventral limits defined, on the more inflated valve, by an irregular, raised rib and, on the flatter valve, by a narrow and shallow rounded groove. Similar though weaker delimiting structures are present in the other species examined. The rib on four of the five available inflated valves of *M. childrenae* is delimited both ventrally and dorsally by a narrow impressed groove, and three of the four less inflated valves have a second shallow groove near the median portion of the area.

The shape and nature of the delimiting structures of the anterior dorsal area is complicated by the manner in which the anterior dorsal margin of the less inflated valve folds over and displaces the adjacent part of the margin of the inflated valve. This tends to accentuate the strength of the rib and the depth of its limiting ventral groove on the inflated valve and usually to broaden and almost erase the groove on the flatter one.

*Lunule.*—The small lunule has become impressed and limited to the right valve, where it lies closely adjacent to the anterior cardinal tooth and projects to fit into a depressed area on the left valve. In most species the lunular projection on the right valve has impinged upon the anterior cardinal to the extent that the combined projecting margin and the tooth serve almost as a single bifid unit (see pl. 2). In some specimens of *M. chipolana*, however, the lunule has almost completely absorbed the cardinal (text fig. 1).

The extent to which the lunule has become impressed into the valve varies considerably between species but is relatively

Text figure 1. Hinge of a right valve of *Miltha chipolana* (Dall) (USNM 646398) in which the impressed lunular margin has almost completely absorbed the anterior cardinal tooth. ($\times$ 1½).

constant within them. It is least impressed in *M. childrenae* (pl. 2, fig. 1a), where it lies almost parallel with the anterior dorsal slope of the valve, making an angle of approximately 65° from the vertical of the valve height and is most deeply impressed in *M. caloosaensis*. In this species the lunule is characteristically concave, with its dorsal one-third to one-half vertical to slightly inwardly sloping and its more ventral portion trending anteriorly at an angle of 35° to 40° from the vertical (pl. 2, fig. 3a). The dorsal portion of the lunule in this species tends to overtop and become closely appressed against the dorsal portion of the anterior cardinal tooth, only the ventral segment of the tooth remaining functional. In *M. carmenae* (pl. 2, fig. 2a) the lunule lies at an angle of about 30° to the vertical, but due to the more steeply sloping anterior dorsal margin of the valve is not as deeply impressed as it is in *M. caloosaensis*. There is more variation in the nature of the lunular area in *M. chipolana* than in any of the other species investigated during this study. This is in keeping with the general trend in that in almost all characters noted, the greatest degree of individual variation occurs in this, the oldest of the western Atlantic species. The extremes of this variation in the lunule are represented in the specimens figured (see pl. 2, fig. 4a and text fig. 1). On the average the lunule is very slightly concave inward and the degree of its immersion varies so that its angle with the vertical ranges from 22° to 40°.

The lunular margin of the left valve is excavated for the reception of the project-

ing lunule of the right. In most specimens the depth of the excavation is approximately equal to the depth of the socket for the reception of the right anterior cardinal tooth. The socket and the excavation are, however, always separated, usually by a slight ridge (see pl. 2, figs. 2b and 4b). In *M. caloosaensis*, where the lunule has impinged most strongly upon the cardinal, and as a result obliterated its dorsal portion, the ridge is more strongly developed and cuts off the dorsal part of the socket becoming fused with the anterior face of the bifid left anterior cardinal tooth.

*Ligament.*—The ligament is deeply inset between the valves, essentially opisthodetic in position and of the paravincular type. The outer lamellar ligament is relatively thin and elongate, occupying almost the entire posterior dorsal area of the valve. It is inserted in a shallow groove that is deeper and more distinct on the relatively inflated valves than it is on those of lesser inflation. The fibrous resilifer lies well below the lamellar ligament and is considerably shorter. It is received upon a long, more or less lanceolate nymph, whose dorsal margin is slightly raised above the level of the hinge plate but whose ventral side is level with or slightly impressed into the plate except at its posterior extremity where it generally rises to the level of the dorsal side. The anterior end of the nymph parallels the thin posterior cardinal tooth of the right valve, and the socket for its reception in the left and curves dorsal to the tooth to extend all the way to the tip of the umbo. In the left valve the nymphal margin is delimited from the cardinal socket by a thin and low shell lamina.

Two of the right valves of *M. childrenae* show a remnant of the fibrous ligament in the extreme dorsal ends of the cardinal sockets, where it is set on a thin shell lamina, and from which it appears to extend on to the inner edge of the lunule. A number of the fossil specimens also show thin shell laminae bridging the dorsalmost extremities of the sockets slightly below their top, and it may well be that in these as in the Recent specimens, the fibrous ligament while functionally opisthodetic was actually slightly amphidetic in position (pl. 4, fig. 4).

It is interesting to note that the fibrous ligament is preserved in all of our fossil specimens. Fibers from the Recent *M. childrenae* when treated with dilute hydrochloric acid reacted with strong effervescence and were dissolved so completely as to leave no visible organic material even under magnification.

A flange projects at right angles to the right valve slightly below its dorsal edge. In all specimens it is broken away except toward the posterior extremity, where it lies immediately above the groove for the reception of the lamellar ligament (see pl. 2, figs. 1a, 2a, 3a, 4a; pl. 4, fig. 4; pl. 5, fig. 3; pl. 7, figs. 2, 4, 5; pl. 3, fig. 2d). The broken anterior end of the flange is almost always at, or but slightly behind, the posterior end of the nymph and the fibrous ligament, and the breakage would seem to be a function of the "bulging" of this portion of the ligament when compressed by the closing of the valves.

*Hinge teeth.*—The hinge, in the adult (pl. 2), consists of two cardinal teeth in each valve, of which the posterior cardinal (**3b**) in the right valve and the anterior (**2**) in the left valve are more or less bifid and more strongly developed than the adjacent right anterior (**3a**) and left posterior (**4b**) cardinals. These latter are simple and tend to be rather lamellose. All teeth are somewhat curved, do not completely cross the hinge plate, and all tend to be somewhat undercut along at least one of their sides.

There is a considerable amount of variation within the individual species, but in general it is evident that the bifid cardinals are most deeply divided in *M. caloosaensis*, least so in *M. chipolana* and *M. carmenae*. In the latter species the younger (*i.e.*, smaller) adult specimens have these teeth somewhat more deeply grooved than in the older and larger forms. In view of this fact it may be that since *M. caloosaensis* is the smallest of the species here studied, the greater degree of bifidity is a result of its smaller average size.

The greatest variation occurs in the right anterior cardinal and is a result of the encroachment of the lunular margin. The most striking result of this encroachment is, as noted above, to be found in *M. caloosaensis* where the dorsal segment of the cardinal is obsolete and aborted. In *M. chipolana* and

*M. carmenae* the anterior end of the cardinal becomes fused against the side of the lunule and the tooth is somewhat shorter than the median cardinal of the same valve. The less deeply impressed lunule in *M. childrenae* overtops the cardinal at its dorsal end and becomes fused against the anterior side of the bifid posterior tooth (pl. 2, fig. 1a) to form a lamellar plate for the reception of the anteriorly projecting ligament. The dorsal end of the anterior cardinal becomes reduced in height but continues under the plate apparently without being otherwise affected by the lunular structure.

### *C. Development of the hinge and associated shell features*

A number of juvenile specimens of *M. chipolana* were secured from matrix washings from Tulane University locality 555 on the banks of the Chipola River, Calhoun County, Florida. Study of these revealed that while the adult specimens of the genus are marked by the absence of anterior and posterior lateral teeth, these are functionally present in the immature stage of development. Furthermore, the lunule, which in the adult is confined to the right valve, is relatively large, lozenge-shaped, and present in both valves. Perhaps most unexpected was the presence of a well-marked, elongate escutcheon in the smaller of the juvenile specimens.

*Lunule.*—In the smallest of the specimens available the lunule and the escutcheon are both relatively large, elongate, lozenge-shaped, and about equally well developed in both right and left valves. The inner margin of the lunule is raised in both valves with the edge of the right slightly projecting only in its more posterior portion where it is adjacent to the anterior cardinal tooth. In this valve the posterior end of the raised lunular margin is continuous dorsal to the cardinal teeth and unites with the anterior end of the small nymph plate (pl. 3, figs. 2a-2d). In the youngest left valves the posterior end of the lunular margin crosses above the dorsal end of the relatively large and deeply bifid anterior cardinal and passes without evident interruption into the dorsal end of the lamellar posterior cardinal (pl. 3, figs. 1a, b). It thus appears that at this early stage of development the lunular margin of the right valve was dorsal to that of the left. During subsequent growth the lunule does not enlarge as rapidly as does the rest of the valve and thus progressively becomes relatively smaller until in the adult it is only a little longer than the right anterior cardinal. During this development the margin of the right impinges more and more over and against the left, the inner edge of which in turn gradually recedes although retaining the raised margin. This becomes narrow and lamellar and persists as a narrow ridge separating the projecting right lunule from the adjacent anterior cardinal tooth. The connection of the left lunular margin with the left posterior cardinal is broken at an early stage of this development, but the dorsal end of this cardinal is above the

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## Plate 2

Typical hinges of species of *Miltha* (ca. × 1.7). Note in the right valves (figs. 1a, 2a, 3a, 4a) the differing shape and degree of submergence of the impressed lunular margin, and the varied effect of this submergence upon the anterior cardinal teeth; and in the left valves (figs. 1b, 2b, 3b, 4b) the depressed area on the hinge plate for the reception of the right lunular margin and the low ridge that separates this area from the anterior adductor socket. In *M. caloosaensis* (fig. 3b) note that the latter ridge becomes a raised lamella that crosses the socket to fuse with the dorsal portion of the bifid anterior cardinal tooth. Figures 2a and 3a also show well the plate-like remnant of the former escutcheon, the anterior part of which is characteristically broken away, apparently by the action of the enlarged fibrous ligament, portions of which are preserved in all specimens. The corresponding left valves show the very narrow groove, distant from the nymph plate, in which was lodged the thin lamellar ligament. Figs. 1a, 1b: *Miltha* (*Miltha*) *childrenae* (fig. 1b being a somewhat immature specimen—the only left valve in the collection); figs. 2a, 2b: *M.* (*M.*) *carmenae* (holotype); figs. 3a, 3b: *M.* (*M.*) *caloosaensis;* figs. 4a, 4b: *M.* (*M.*) *chipolana.*

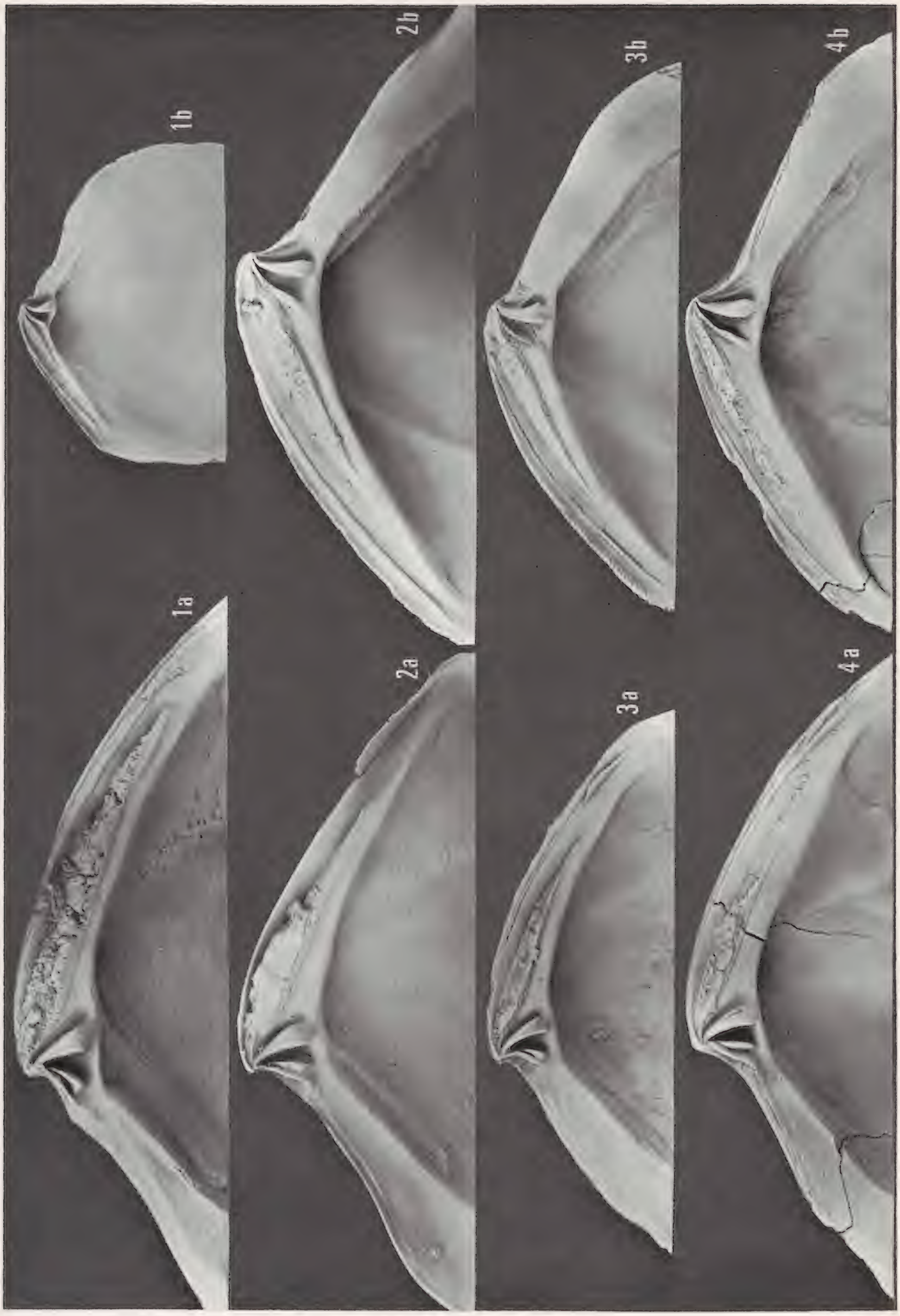


PLATE 2

end of the anterior cardinal at all stages of growth.

*Escutcheon.*—As indicated above, the discovery of a well defined escutcheon present on the more immature valves was quite unexpected, especially since this structure is typically absent in almost all lucinids, except in species of the genus *Myrtea* Turton, 1822. The smallest specimens of *Miltha chipolana* here studied possessed a rather large escutcheon that extended from immediately behind the umbo almost the full length of the posterior dorsal margin. It is almost flat, at right angles to the rest of the valve surface, smooth except for fine lines of growth, and is delimited on its outer side primarily by a series of raised, somewhat thickened ends of the growth lamellae that ornament the main posterior area of the valve, including the dorsal area. In sum total of its features this escutcheon is like that to be seen on *Chione cancellata* (Linnaeus).

As growth proceeds the outer edge of the escutcheonal area appears to rise progressively above the flattened surface. The area of the right valve, as in the development of the lunule, displaces the escutcheonal margin of the left until it is wholly below the projecting valve surface, its former presence marked only by a low ridge dorsal to the groove in which the lamellar ligament is inserted. The "flange" that projects at right angles to the dorsal part of the right valve (see page 101) is the remnant of the escutcheon. It apparently falls victim to the pressures developed by the enlargement of the fibrous ligament, for even in relatively small specimens (pl. 3, fig. 2d; 11.2 mm in length) it has been broken away dorsal to the area occupied by that structure.

*Hinge.*—The cardinal teeth of the hinge in the immature specimens are similar to those of the adult, the only differences being that the left anterior cardinal is proportionately more trigonal and more deeply bifid, and the left posterior somewhat more robust in the immature form. Initially all cardinal teeth except the right anterior one occupy the full width of the hinge plate.

The striking difference between the juvenile and adult hinges is the presence in the former of anterior and posterior lateral teeth. In these specimens, single small and more or less elongate laterals are present in the left valves that are received in rather prominently developed sub-marginal sockets in the right valves. In the left valve immediately below the anterior end of the well-defined lunule there is an almost nodular anterior lateral tooth (**AII**) the dorsal side of which is continuous with the raised lunular margin, giving the tooth the superficial appearance of being somewhat obliquely transverse to the trend of the hinge plate (pl. 3, figs. 1a, 1b). This tooth is received, in the right valve, in a distinct and prominent socket that occurs between the raised lunular margin and a strong, elongate, anterior lateral (**AI**) that, in the smallest specimen available, appears to arise more from the dorsal side of the valve interior than from the inner edge of the hinge-plate itself (pl. 3, fig. 2b). In all larger specimens (pl. 3, figs. 2a, 2c) it is located upon the inner edge of the plate. This tooth is sub-triangular in profile with its apex situated below the anterior end of the lunular margin. As growth proceeds and the lunular area becomes proportionately smaller, the right lateral tooth becomes relatively more and more elongate and more anterior in position with respect to the portion of the lunular margin that initially formed its opposite element of the lateral socket. As it loses its function as a confining element for the left anterior lateral it becomes reduced in height but persists into the adult hinge, where its presence is marked by a low and inconspicuous raised ridge that

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PLATE 3

Development of the hinge and associated features in *Miltha* (*Miltha*) *chipolana* (Dall). All figured approximately × 9.6; all specimens from Tulane University locality TU 555, Chipola Formation, Chipola River, Florida. Figures 1a-d, left valves: 1a, USNM 646403; 1b, USNM 646404; 1c, USNM 646405; 1d, USNM 646406. Figures 2a-d, right valves: 2a, USNM 646399; 2b, USNM 646400; 2c, USNM 646401; 2d, USNM 646402.

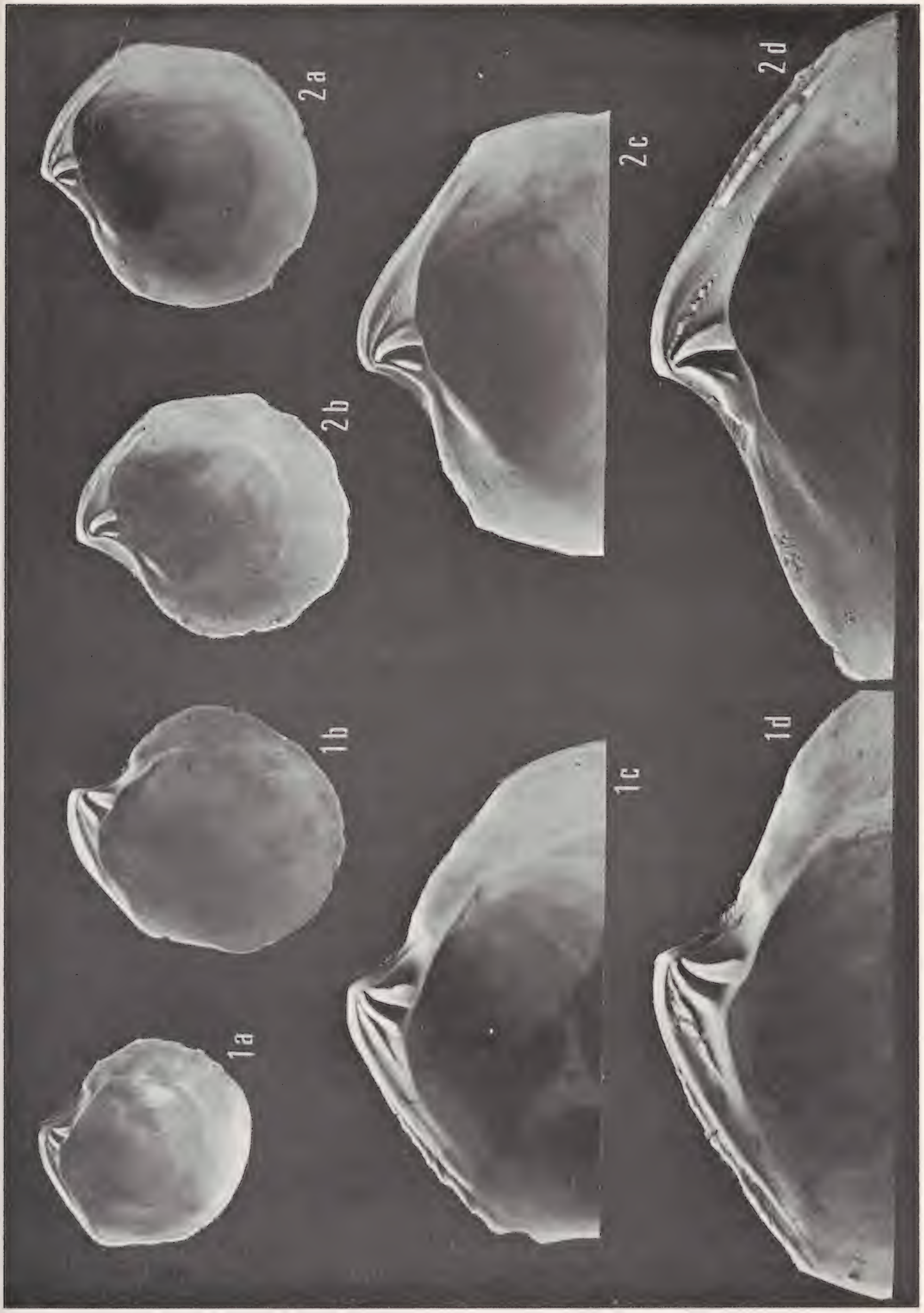
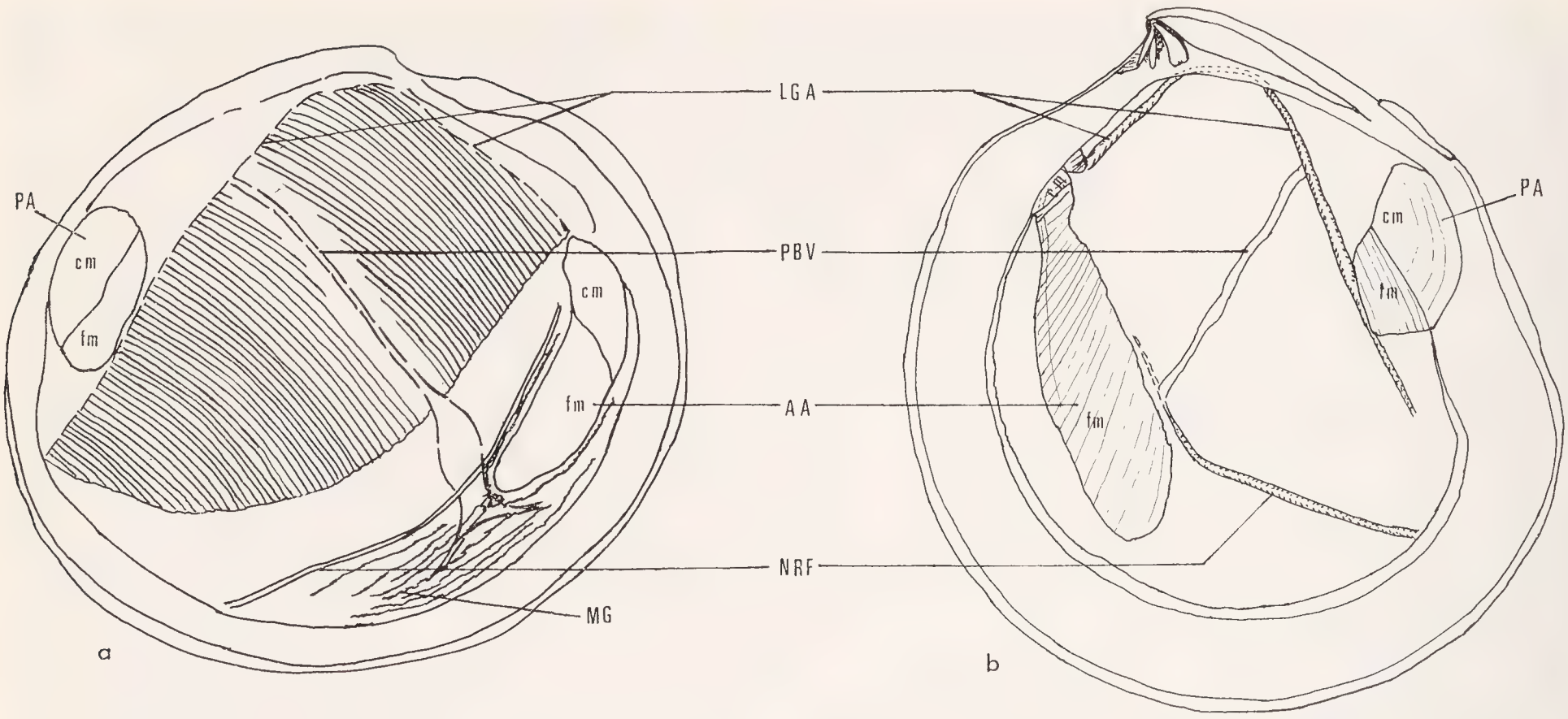



PLATE 3




Text figure 2. Comparison of some features of the anatomy of *Codakia orbicularis* (Linnaeus) —figure a (modified after Allen, 1958, text figures 3 and 29), with markings on the interior of the valves of *Miltha*—figure b. AA—anterior adductor muscle and scar; LGA—line of gill attachment and corresponding ridge in *Miltha*; MG—"mantle gills" of *C. orbicularis*; NRF—"non-ridged fold" of mantle and corresponding ridge on shell of *Miltha;* PA—posterior adductor muscle and corresponding scar; PBV—pallial blood vessel in *Codakia* and corresponding groove in shell of *Miltha.* The letters "cm" and "fm" indicate the areas of "catch" or non-striated muscle fibers and of the "fast" or striated muscle fibers comprising the adductor muscles.

margins the anterior ventral side of the hinge-plate. This marginal ridge is present in all of the species examined.

The left anterior lateral becomes weakened and lost as the adjacent lunular margin is depressed by the enlargement of that of the right. There is some suggestion however (see pl. 3, fig. 1d), that it develops a low anterior ridge-like projection, which forms the low ridge margining the antero-ventral side of the hinge-plate in that valve.

The posterior lateral of the left valve (**PII**) is essentially a slender elongate ridge that occupies the full width of the narrowed hinge plate. The top of this ridge is raised slightly above the level of the projecting margin of the escutcheon, which otherwise is higher than the hinge-plate, being separated from that margin by an inconspicuous, shallow groove (pl. 3, fig. 1a, b). This tooth is received in an elongate socket that develops between the raised escutcheonal margin of the right valve and a long, slender, ridge-like posterior lateral tooth (**PI**) developed on the ventral margin of the hinge-plate at its posterior end. Both the left and right laterals die out as the escutcheonal structure is transferred to the right valve and then broken away by the growing fibrous ligament. The posterior portion of the hinge-plates of right and left valves have no areas of contact with each other in any of the adult valves examined and it is evident that no traces of the posterior lateral tooth structures remain at that stage of development.

### D. *Structures on interior of the valves and their interpretation*

No study has been made of the anatomy of either of the two Recent species of *Miltha.* Observation of the markings present on the interior of the valves of the species of *Miltha* examined during the present investigation, interpreted in the light of published anatomical studies of species of other genera of Lucinidae (see especially Allen, 1958), serve, however, to permit suggestions as to certain aspects of milthoid anatomy. These internal markings include, in addition to the usual adductor muscle and pallial line scars, two, and occasionally three, linear grooves and ridges[2] that appear to mark the site of important body structures (text fig. 2).

[2] It should be noted that the terms "grooves" and "ridges" are here used with respect to the structures visible on the interior of the valve, and that these would be the reverse of the structure present on the mantle area—a "ridge" on the shell reflects a "groove" in the mantle.

*Gill attachment ridge.*—Most prominent of these structures is a ridge that corresponds with the line of attachment of the gill demibranch with the mantle. This extends dorsally from below the most anterior extremity of the posterior adductor scar to a point under the hinge line then bends sharply to trend antero-ventrally subparallel with and just beneath the margin of the hinge plate to a termination at the dorsal side of the small anterior retractor scar. In the less inflated valve the thickening developed along this ridge serves to seal off almost completely the sub-umbonal portion of the valve area. In *M. chipolana*, M. *caloosaensis* and *M. carmenae* the posterior segment of the ridge passes under the hinge plate at a position almost directly under the mid-length of the projecting nymphal plate; in *M. childrenae* the termination is about at the anterior third of the length of the plate. Judging from the illustration given by Keen (1958, p. 99, sp. 198) it is even more anterior in position in the Pacific species *M. xantusi* Dall, lying at a point that would coincide with the prolongation of the posterior cardinal tooth. In *M. carmenae* the ridge is almost straight, while in all of the other species it is slightly arcuate anteriorly towards its dorsal end, being most strongly curved and hence terminating more anteriorly in *M. childrenae.*

*Pallial blood vessel groove.*—A second, usually well-marked structure occurs in the form of a groove that has a diagonally postero-dorsal trend from a point ventral to the midlength of the anterior adductor scar to an intersection with the posterior segment of the gill attachment ridge. This intersection occurs approximately at a point that would coincide with the crossing of the ridge by a line connecting the dorsal terminations of the two adductor scars (see text fig. 2). This groove marks the position of the large pallial blood vessel that passes from the auricles to the sinuses in the mantle. In most specimens the trend of the groove is almost straight, though minor meandering may occur. There is variation in the angle of trend, the antero-ventral end being somewhat lower with respect to the length of the anterior adductor in *M. chipolana* and *M. carmenae* than it is in *M. caloosaensis* and *M. childrenae.* Keen's figure of *M. xantusi*, mentioned above, suggests that this species has a more ventrally situated anterior termination of this groove than that of any of those here studied.

There is also variation in the trend of the groove on opposite sides of the body of the same individual, apparently a result of the differing convexities of the valves. In the majority of the flatter valves the groove can be observed to pass up onto the crest of the gill attachment ridge, and in a few specimens it crosses that ridge before disappearing, apparently at the point where the pallial vessel passes laterally into the pericardial region. In the more inflated valves the groove does not transgress on the ridge but dies out immediately adjacent to it suggesting that the pericardial area was slightly more remote from the mantle on the more rounded side of the body. In few inflated valves, however, there is what is apparently a shallow prolongation of the groove trending dorsally parallel and immediately adjacent to the inner side of the ridge. The significance of this change of direction is not apparent unless it be that the lateral compression indicated by the lesser inflation of one of the valves results in a slight offset of one auricle with respect to the other.

The interpretation of this groove as marking the position of the pallial blood vessel is borne out by a comparison of the figures showing the position of this structure in the species studied by Allen (1958) with the shells of the same forms in the Tulane University collections. In all of these species the shells show some trace of a groove in the region indicated by Allen as being the site of the pallial vessel. Usually the groove is more pronounced (more deeply impressed) in the relatively compressed, thicker-shelled species—*e.g.*: *Lucina pennsylvanica* (Linnaeus) (Allen, fig. 4, p. 431, and fig. 19, p. 442), *Codakia orbicularis* (Linnaeus) (Allen, fig. 3, p. 430, and fig. 29, p. 452), *Codakia* (*Jagonia*) *orbiculata* (Montagu) (Allen, fig. 30, p. 452); less deeply impressed and accordingly more difficult to detect in the more inflated and usually thinner shelled species—*e.g.*: "*Lucina* (*Loripinus*) *chrysostoma* Meuschen" [= *Anodontia alba* Link] (Allen, fig. 18, p. 441) and *Divaricella* [= *Divalinga*] *quadrisulcata* (d'Orbigny) (Allen, fig. 17, p. 441).

In all of these species the ventral termi-

nation of the pallial vessel and of the consequent groove on the interior of the shell occurs at a point behind the postero-ventral end of the elongated anterior adductor muscle. This is in contrast to its position in the species of the genus *Miltha sensu stricto.* In these the ventral termination of the groove occurs closely adjacent to the inner side of the adductor well above its postero-ventral end.

*Non-ridged mantle fold.*—A third structure and one that is most commonly to be noted on the interior of the valves of the larger specimens in the collections, consists of a rather weak ridge trending anterodorsally from a point coincident with the inner margin of the pallial line almost to the posterior side of the anterior adductor scar before turning to parallel the adductor to and beyond the pallial blood vessel groove. The ridge, which has been observed in all of the species at present under study, is most strongly developed in the area between the pallial line and the adductor scar but becomes greatly weakened as it parallels the scar and is but seldom visible above the pallial vessel groove.

The ridge appears to mark the position of the "non-ridged fold" of Allen (1958, p. 430, text figs. 3, 29), which he describes and figures as occurring in *Codakia orbicularis* (Linnaeus) and compares with that reported by Pelseneer (1911, p. 39) as occurring in "*Lucina exasperata*" [= *Codakia tigerina* (Linnaeus)]. According to Allen this fold marks the inner margin of the area of "mantle 'gills'" which are wrinkles or "convoluted folds of the inner mantle epithelium." Allen also states (p. 431) that "it seems probable that these 'gills' are respiratory in function . . . Not only are all the pallial blood spaces greatly extended but a large pallial blood vessel is present. This vessel is largest in those species with mantle gills." Allen also notes that the "non-ridge fold" in *Codakia orbicularis* "extends from the palps to the posterior limit of the other folds."

Examination of specimens of *Codakia* in our collections revealed that a faint ridge, similar to, but weaker than that here noted in the species of *Miltha*, may occasionally be seen on the shells of older, more or less gerontic specimens of *Codakia orbicularis*, *Codakia tigerina*, and *Codakia punctata* (Linnaeus). It therefore seems probable that when the anatomy of *Miltha* becomes known "mantle 'gills'" will be found to occur, and judging by the strength of the "non-ridged folds" as compared to those observed in the species of *Codakia*, that these 'gills' will be exceptionally well developed.

*Adductor muscle scars.*—The posterior adductor scars of the several species of *Miltha* clearly show a differentiation into two elements. The outer portion is smooth or marked by weakly defined "growth lines" that curve parallel with the posterior and ventral edges of the scar. The inner portion, distinctly separated from the outer by an impressed line that appears almost a prolongation of the pallial line, is marked with sub-parallel grooves that trend almost vertically in a dorso-ventral direction. Such differentiation is not well-shown on the anterior adductor scars, which tend also to exhibit sub-parallel grooving that, however, trends sub-diagonally across the muscle attachment area rather than dorso-ventrally. Some specimens possess a slightly more pronounced groove that sets off a small, subtriangular dorsal end of the scar. This

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PLATE 4

*Miltha* (*Miltha*) *childrenae* (Gray) ..... 116

Figs. 1, 2. USNM 679267-A, right valve of lesser inflation, height 86.2 mm, length 76.6 mm. 1, exterior of valve; 2, interior of valve.

Figs. 3, 4. USNM 679267-B, inflated right valve of smaller individual, height 58.3 mm, length 54.8 mm. 3, exterior of valve; 4, oblique view of hinge and ligamental area (× 3.25). Note remnant of fibrous ligament on inner edge of produced lunular margin, and on small platform at dorsal end of cardinal socket, suggesting a slightly amphidetic ligament.

All specimens from U. S. Fish and Wildlife Service M/V *Oregon* locality 4228, Lat. 20°02′ South, Long. 43°17′ West, 28 fathoms, bottom temperature 84°F. Figs. 1-3 natural size.

PLATE 4

portion usually is also transversely grooved but the grooves are more weakly incised than are those on the ventral segment.

Specimens of *Codakia orbicularis* in our collections exhibit a marking of the posterior adductors that is almost identical to that of the species of *Miltha*. The anterior adductors also have transverse markings on the more ventral parts, but some specimens show a larger dorsal area with only weakly defined "growth lines," as in the posterior scar. These areas of differing "ornamentation" on the muscle scars of *C. orbicularis* agree rather closely with areas of muscle-type differentiation shown in the figures of this species given by Allen (1958, text fig. 28; areas not specifically labelled) and (text fig. 1c) of *Loripes lucinalis* (Turton). In the latter figure the areas are distinguished as being the sites of the "'catch' muscle" and the "'quick' muscle," with the former occupying the dorsal portion of the anterior adductor and the posterior segment of the posterior adductor.

As well summarized by Hoyle (1964, *in* Wilbur and Yonge, vol. 1, p. 315): "The lamellibranch adductors are sometimes divided by a connective tissue sheet into two portions, one of which is composed of smooth muscle fibers (*e.g.*, *Pecten*, *Ostrea*, *Modiolus*). . . . The histological division is correlated with a functional one, the striated portion contracting very quickly and being referred to as the 'fast' portion [= 'quick' muscle of Allen], while the non-striated is much slower and is referred to as the 'slow' portion [= 'catch' muscle of Allen]. It is the slow portion which is principally responsible for the long-maintained, economical contractions which keep the valves closed on exposure, though it is doubtless assisted by periodical contractions of the fast portion in the animal."

I have been unable to locate any specific study of the structure of the muscles of the Lucinidae. An examination of the table given by Bowden (1958, pp. 300-301) would suggest that the so-called "striated portion" probably is of the "doubly obliquely striated type" since true transversely striated muscle is reported only in *Anomia*, *Lima*, *Pecten* (incl. *Chlamys*), *Spondylus*, and *Teredo*. As noted by Hoyle (1961, p. 315) electron microscope studies by Hanson and Lowy have shown that these doubly obliquely striated fibers are "smooth fibers with peripheral, twisted fibrils, rather than fibers with a unique form of cross banding."

Whatever the basic nature of the muscle fiber structure, it appears that the adductor muscles in *Miltha* consist of two differing muscle fiber types. The outer, relatively smooth posterior segment of the posterior adductor and the small, dorsal portion of the anterior adductor would, by analogy with the areas indicated by Allen in his figure of *Loripes lucinalis*, consist of non-striated or "smooth" muscle fibers, while the smaller, vertically grooved, inner area of the posterior adductor scar and the large, transversely grooved area of the anterior adductor scar would be occupied by the so-called "doubly obliquely striated" type of muscle fibers. The impressed line or groove separating the two areas on the adductor scars would thus mark the location of the

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PLATE 5

*Miltha* (*Miltha*) *chipolana* (Dall) ..... 118

Figs. 1, 4. USNM 646395, height 64.2 mm, length 59 mm. 1, exterior of more inflated left valve; 4, exterior of less inflated right valve. Locality TU 459.

Figs. 2, 3. USNM 646394, height 72.6 mm, length 67.6 mm, diameter (paired valves) 20.7 mm. 2, exterior of more inflated right valve; 3, dorsal view of paired valves. Locality TU 555.

Fig. 5. USNM 646397, height 46.6 mm, length 42.5 mm. Exterior of left valve of lesser inflation, ecotypic variety (?) with unusually straight anterior dorsal margin and subangulate anterior dorsal end; type of *M. smithwoodwardi* (Maury) is a shell of this general outline. Locality TU 549.

Fig. 6. USNM 646396, height 82.9 mm, length 81 mm. Exterior of right valve of lesser inflation illustrating the more elongate variant of this species. Locality TU 820b.

All figures are approximately natural size.

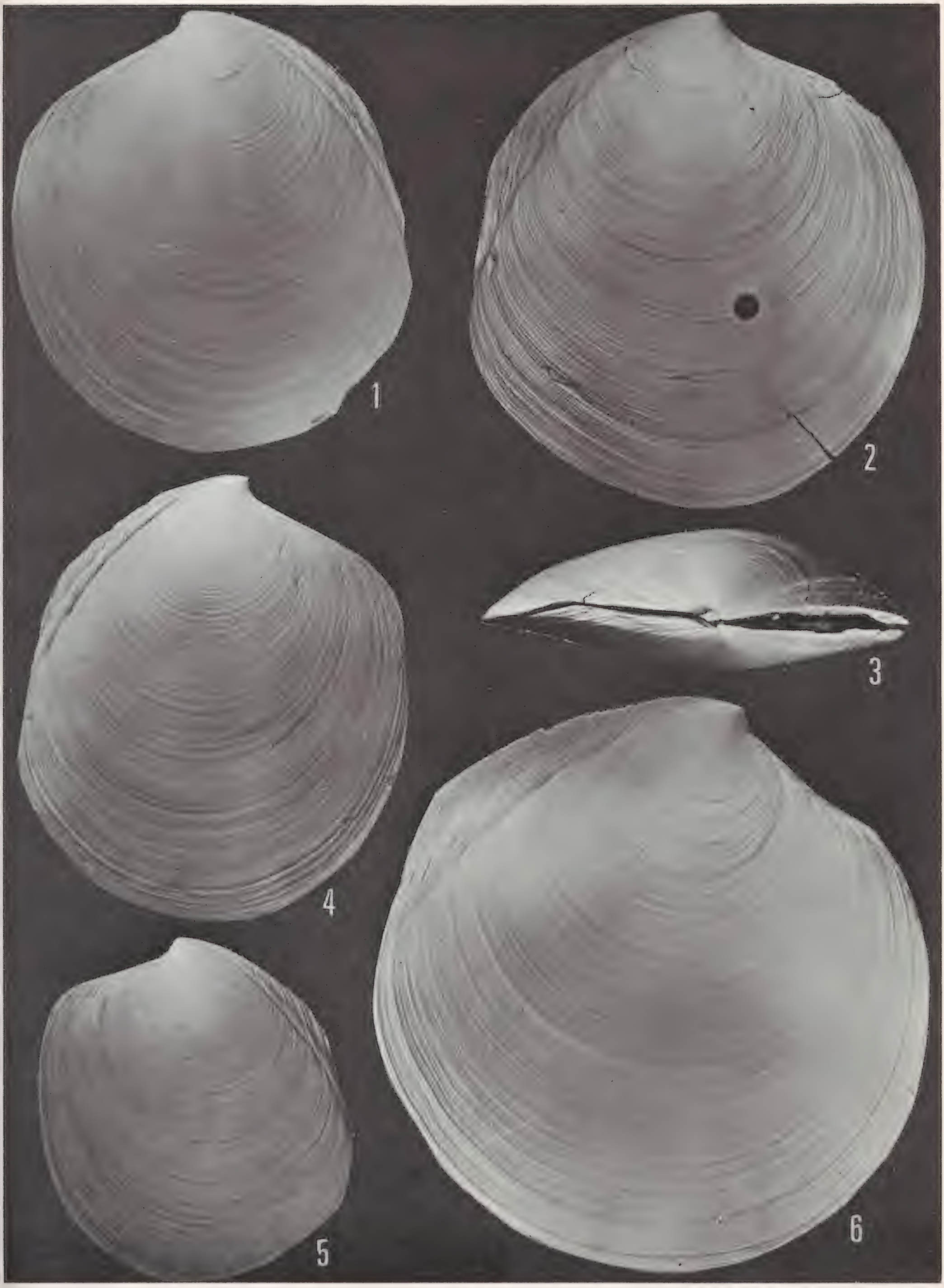


PLATE 5

sheet of connective tissue that separates the two portions of the respective muscles. If this interpretation be correct then the "slow" or "catch" segment of the muscle arrangement is much larger in the posterior adductor with the "fast" or "quick" segment correspondingly enlarged in the anterior adductor. Whether or not this seeming "division of labor" is a result of the development of an anterior inhalant tube in *Miltha,* as in many other Lucinids, can only be determined when specimens of the living animal are available for study.

### *E. Ecological Observations*

There is little available published information on the ecologic requirements of species of the genus *Miltha.* The specimens of *M. childrenae* taken by the M/V *Oregon* at station 4228 (see page 118) were from 28 fathoms, bottom temperature 84°F [= 30°C]; this is the only record for this species that I have been able to find. Small patches of fine-grained, rather angular, quartz sand were present on some of the specimens. Hertlein and Strong (1946, p. 115) report *M. xantusi* from the Arena Bank, off Baja California, "33 fathoms, sand, weed." Keen (1958, p. 98) reports that most known specimens of *M. xantusi* were taken "off Cape San Lucas, in depths of 30 or more fathoms."[3] Durham (1950, p. 1248) lists *Miltha* among those genera indicative of tropical seas in that they live in water with a minimum temperature of 20°C or warmer, while Hall (1964, map, p. 231) indicates that Cape San Lucas lies at the northern edge of the "Inner Tropical Zone" where (p. 229) "the marine water temperature is 25°C or approximately 75°F for nearly 12 months of the year."

According to Allen (1958, p. 425-427) most species of Lucinidae appear to live in sands or muds where the organic content is low or absent, and many show "a marked tendency . . . to live among the roots of marine grasses . . ."

[3] Dr. A. Myra Keen has informed me (*in litt.*) that the Stanford University collections contain four valves of this species collected by the *Ariel* Expedition, in 1960, from off Cabo Haro, near Guaymas, Mexico, in 15 to 25 fathoms. This represents a considerable extension of the range of this species into the Gulf of California, although still within the "Inner Tropical Zone" of Hall.

While studying the collections I was struck by the relative rarity of shells showing evidence of having been bored by molluscan predators. A tabulation revealed that only 33 of the 450 valves checked were so damaged. What was even more striking was that 32 of these 33 valves were of the more inflated type; only one flatter valve had been attacked. This had been attacked twice, although only one hole had been drilled through into the interior of the shell (pl. 6, fig. 5) and this was a small hole suggesting attack by a relatively immature predator.

The low incidence of predation would seem to suggest that *Miltha*, like most other lucinids, is a relatively deeply burrowing form. An explanation for the strong tendency for the predators to attack the inflated valves is not readily apparent. It would seem that if the animal lived with a vertical or sub-vertical orientation of the valves, a predator burrowing through the substrate would have had almost an even chance of coming upon either the flatter or the more inflated valve. But the incidence of boring of the inflated valve is 15.9 percent of the 201 such valves in the present collections while only 0.4 percent of the 249 less inflated valves has been attacked. The only plausible explanation that occurs to me at this time is to suggest that a predator might come upon either the anterior inhalant tube or the posterior siphonal tube and follow these down until they found the shell. This would imply that *Miltha* lives in a more or less horizontal position with the inflated valve uppermost.

### *F. Notes on Origin and Geologic History of* Miltha

Chavan, in his "Essai Critique de Classification des Lucines" (1937-1938), suggested that *Miltha* was derived from a Jurassic form of *Mesomiltha* or *Saxolucina* (1938, table, p. 242). He had previously noted (1938, p. 72) that there was in the "Astartien de Cordebugle (Calvados) une espèce remarquable de *Saxolucina*"[4] and it is probable that this was the species that

[4] *Saxolucina substriata* Chavan, 1937, Jour. de Conchyl., vol. 81, p. 72 (non "*Lucina*" *substriata* Roemer, questionably considered to be a *Saxolucina* by Chavan, 1938, p. 72) = *Discomiltha oehlerti* Chavan, 1952.

he had in mind when he suggested the possibility of a Jurassic saxolucinid ancestral form. However, when he later described the Cordebugle fauna he renamed this species and made it the type of a new genus *Discomiltha* (1952, p. 95) "sans relation directe avec les *Miltha*" (p. 96). It should be noted that although *Discomiltha oehlerti* has a superficially *Miltha*-like external shape, it lacks the distinctive anterior and posterior areas on the valve and appears to have both valves equally inflated. The hinge structure is similar to that of *Saxolucina saxorum* (Lamarck), the Lutetian-Bartonian type species of *Saxolucina* Stewart (1930, p. 184) and so far as can be determined from Chavan's illustration of the right valve (1952, pl. 3, fig. 39), the trend of the pallial blood vessel groove is identical with that to be observed in the figure of the interior of the valve of *S. saxorum* given by Cossmann and Pissarro (1906, pl. 25, sp. 83-23). The derivation of *Saxolucina* from *Discomiltha* seems quite probable, but there is little evidence suggesting any relationship to *Miltha*.

The hinge of "*Lucina*" *pulchra* Zittel and Goubert, the type species of *Mesomiltha* Chavan (1938, p. 231, as subgenus of *Cavilucina* Fischer), as figured by Chavan (1938, p. 233, text fig. 20), differs from that of the immature valves of *Miltha chipolana* (see pl. 3, figs. 1a, b, 2a, b) in having a much narrower hinge plate and more anteriorly situated anterior lateral teeth. More significantly, there is no trace of an escutcheon, which is so prominently developed in the young of *Miltha*.

The earliest species with which I am acquainted that appears probably to be referable to *Miltha s.s.* is the middle Eocene Domengine Formation species "*Lucina*" *packi* Dickerson (1916, p. 484, pl. 36, fig. 12). The type of this species is a very small and immature individual, but larger specimens, which I figured (1939, pl. 10, figs. 8, 12) as *Miltha* (*Eomiltha?*), show a typically milthoid external ornamentation including defined anterior and posterior dorsal areas (fig. 8), and hinge and internal margins (fig. 12). The two separate valves available at that time were collected from different localities and were too closely similar in degree of inflation to permit observation as to whether or not this early form of *Miltha* possessed the characteristic differing inflation of opposite valves that is so marked in the Neogene species.

Chavan (1938, p. 61) interprets the Montian, Paleocene, *Phacoides montensis* Cossmann (1908, p. 15, pl. 2, figs. 1-10) as "une vrai *Miltha*" and apparently as the oldest representative of the genus. But as illustrated by Cossmann this species possesses small anterior and posterior lateral teeth in specimens exceeding 50 mm in height. The anterior laterals are very different in nature and relative position from those to be observed in the young *Miltha chipolana*, and are present in addition to a raised ventral margin of the anterior portion of the hinge plate which, as noted above (p. 106) appears, in the Florida Miocene species at least, to have been derived from the lateral teeth. The Montian species seems not to have had any differing amount of inflation of the two valves. However, the general outline and surface ornamentation, including both anterior and posterior dorsal areas, the nature of the cardinal dentition and of the pallial line, which is distant from the valve margins, as well as the shape and position of the adductor scars are all very similar to features characteristic of *Miltha s.s.*, and the species must be considered as close to, if not directly ancestral to, this group.

*Miltha* has been reported from the Eocene and Oligocene of Peru by Olsson who (1930, p. 23) clearly was following Dall (1903, p. 1374 *et seq.*) in his broad interpretation of the genus. Of the three species mentioned by Olsson, *Phacoides* (*Miltha*) *woodi* Olsson (1930, p. 23, pl. 2, figs. 9, 12) has the distinctive outline and biconvex shell of *Eomiltha*, "*Lucina*" *paytensis* Woods (1922, p. 70, pl. 4, fig. 5) appears to be a species of the genus *Claibornites*, Stewart, 1930, and *Phacoides* (*Miltha*) *conventus* Olsson (1929, p. 75, pl. 11, fig. 3 [pl. 3, fig. 3 of separate]) is said by Olsson to be "closely related to *P.* (*Miltha*) *claibornensis* Conrad," type species of *Plastomiltha* Stewart, 1930.

So far as I am aware no upper Eocene or Oligocene species that can be certainly referred to *Miltha s.s.* have yet been reported in the paleontologic literature. By the beginning of the Miocene, however, *Miltha* was widely distributed, appearing almost

simultaneously in the lower Miocene of California—"*Phacoides (Miltha)" sanctae-crucis* Arnold (1910, p. 57, pl. 6, fig. 6) of the Vaqueros Formation[5]; of Florida—"*Phacoides (Miltha)" chipolanus* Dall (1903, p. 1375, pl. 51, fig. 11) of the Chipola Formation; and of New Zealand—*Miltha neozelanica* Marshall and Murdock (1921, p. 78, pl. 16, pl. 17, fig. 1) reported to range from the Waitakian, Lower Miocene, to the Waitotaran, Pliocene, stages. *Miltha* is also known from the Miocene of Argentina—*Miltha iheringiana* Doello-Jurado (1919, p. 558, text fig.) of the Entrerriennne Formation.

*Miltha* has been reported to have reached South Australia and Tasmania in the upper Miocene. The illustrations of the fragmentary representatives of the South Australian "*Miltha (Milthoidea) grandis* (Hooper Woods, 1931)"[6] given by Singleton and Woods (1934, p. 208, pl. 8, figs. 1a, b, 2a, b, 3) reveal a hinge of distinctly milthoid aspect. The peculiarly crenulated margin shown in their figure 3 is, however, a feature not represented in any species of *Miltha (Miltha)* known to me, and if not a pathologic manifestation would probably suggest that these represent a distinct, undescribed subgenus.

Singleton and Woods also described a *Miltha (Milthoidea) grandis* subspecies *flindersiana* (1934, p. 210, pl. 8, figs. 4a, b) from the "very late Tertiary or post-Tertiary" of Flinders Island, Tasmania. This form was separated as a distinct species by Wilkins (1962, p. 43, pl. 5, figs. 1, 2) who stated that it is of lower Pliocene age. It does not have a crenulated internal margin but, according to Wilkins, possesses "an obsolete anterior tooth . . . on the right valve." Presumably this must refer to an obsolete anterior lateral tooth since there is a well developed anterior cardinal shown both in the original figure as well as in that given by Wilkins. This feature, as well as the trend of the pallial vessel groove, which is more oblique than that observed in species of *Miltha (Miltha)*, passing downwards to the posterior end of the anterior adductor scar, suggests that this species is more accurately referred to *Eomiltha* Cossmann, 1911.

Dartevelle and Roger (1954, p. 285 report a "*Miltha" harrisi* from beds that they assign to the Burdigalian, Miocene, of Angola. This paper has not been available to me, but I note in the Zoological Record for 1955 that *M. harrisi* is said to be a new name for the *Lucina* cf. *L. landanensis* Newton of Caster (1938, p. 24, pl. 1, figs. 1, 2), described as being from deposits of Eocene age, and said to have an edentulous hinge. This latter feature clearly removes the species from *Miltha s.s.*, and suggests a referral to the genus *Pseudomiltha* Fischer, 1887.

[5] Khomenko, 1938 (Trans. Geol. Oil Inst., Ser. a, fasc. 103, p. 43, pl. 8, fig. 2, pl. 9, fig. 5) has reported this species from the early Miocene of northern Sakhalin. The figures given, of two broken specimens, are not adequate to permit evaluation of the record beyond establishing the occurrence of a large lucinid species in the fauna.

[6] This species was described by Hooper Woods (Trans. Roy. Soc. S. Australia, vol. 55, p. 148, pl. 7, figs. 5, 6) as *Dosinia grandis,* a name that is preoccupied by *D. grandis* Nelson, 1870 (Trans. Connecticut Acad. Sci., vol. 2, p. 201). The substitute specific name *hora* has been proposed by Cotton (1947, Rec. S. Australian Mus. vol. 8, no. 4, p. 663).

→

PLATE 6

*Miltha (Miltha) caloosaensis* (Dall) ..... 121

Figs. 1, 2, 4. USNM 646407, height 61.9 mm, length 55.5 mm, diameter (paired valves) 15.4 mm. 1, exterior of left valve of lesser inflation; 2, exterior of more inflated right valve; 4, dorsal view of paired valves. Locality TU 796 (upper Miocene).

Figs. 3, 5. USNM 646408, height 55. 2 mm, length 49.8 mm. 3, exterior of more inflated right valve; 5, exterior of left valve of lesser inflation. Locality TU 755 (Pliocene.)

All figures approximately natural size.

*Miltha (Miltha) carmenae* H. E. Vokes, new species ..... 122

Fig. 6. Paratype, USNM 646410, height 105.5 mm, length 98.8 mm. Exterior of left valve of lesser inflation (× .9). Locality TU 201.

PLATE 6

## V. Miltha (Miltha) childrenae (Gray)

Plate 1, Figure 1; Plate 2, Figures 1a, b; Plate 4, Figures 1-4

1824, *Lucina Childrinae* [sic] Gray, Zoölogical Journal, vol. 1, p. 221.
1825, *Lucina Childrenae* Gray, Ann. Philos., (n.s.) vol. 9, p. 136.
1825, *Lucina Childreni* Gray, Sowerby, Cat. Shells Coll. Earl of Tankerville, p. 11.
1826, *Lucina Childreni* Gray, Sowerby, Gen. Shells, Pt. 27 "*Lucina*," fig. 2.
1828, *Tellina Childreni* [Gray], Wood, Index Testaceologicus, ed. 2, Supplement, p. 3, pl. 1, *Tellina* fig. 1.
1841, *Lucina Childreni* Gray, Reeve, Conch. Systema, vol. 1, p. 82, pl. 59, fig. 2.
1842, *Lucina Childreni* Gray, Hanley, Cat. Recent Bivalve Shells, p. 79.
1850, *Lucina Childreni* Gray, Reeve, Conch. Icon., "*Lucina*," pl. 3, sp. 12.
1857, [*Lucina* (*Miltha*)] *Childreni* Gray, H. and A. Adams, Genera Recent Moll., vol. 2, p. 468.
1862, *Lucina* (*Miltha*) *Childreni* Gray, Chenu, Man. Conch., vol. 2, p. 120, fig. 579.
Not 1864, *Miltha Childreni* [Gray], Carpenter, Rept. Brit. Assoc. Adv. Sci. for 1863, p. 620 [= *M. xantusi* Dall, 1905].
Not 1901, *Phacoides* (*Miltha*) *childreni* Gray, Dall, Proc. U. S. Nat. Mus., vol. 23, p. 812 [= *M. xantusi* Dall, 1905].
Not 1903, *Phacoides* (*Miltha*) *childreni* Gray, Dall, Trans. Wagner Free Inst. Sci., vol. 3, pt. 6, p. 1377 [= *M. xantusi* Dall, 1905].
1905, *Phacoides* (*Miltha*) *childreni* Gray, Dall, Nautilus, vol. 18, no. 10, p. 110-112.
1907, *Phacoides Childreni* Gray, Von Ihering, Anales Mus. Nac. Buenos Aires, vol. 14 (3rd. ser., vol. 7), p. 530.
1921, *Miltha Childreni* Gray, Lamy, Journ. de Conchyl., vol. 65, p. 120, text fig.
1957, *Miltha childrenae* (Gray), Wilkins, Bull. Brit. Mus. (Nat. Hist.), Hist. Ser., vol. 1, no. 4, p. 159, pl. 23, fig. 6.

The first mention of this species occurs in a footnote appended to a series of "Conchological Observations" published by Gray in the Zoölogical Journal, vol. 1. This has been cited by Dall and others as of 1825, but Wilkins (1957, p. 159) gives the date of publication as June, 1824. It is also of interest to note that Sowerby, in 1825, in his "Catalogue of the Shells contained in the collection of the late Earl of Tankerville" notes (p. 11, sp. 206): "*Lucina Childreni* (a.b.) Gray, in Annals of Philosophy (1824) 2 specimens: one being the reverse of the other." The reference to the Anals of Philosophy was, apparently, a *lapsus*, since the letter of transmittal of Gray's description in that publication is dated "British Museum, Jan. 10, 1825" and the number in which it appeared is dated as "Feb. 1825."[7] As further circumstantial evidence that the Sowerby citation to the Annals of Philosophy was an error for the reference in the Zoological Journal is the fact that the latter was concerned with the "2 specimens: one being the reverse of the other" that were in the Tankerville collection. Concerning these Gray (1824, p. 221) states: "There are two specimens of a new Lucina, in the Tankerville collection, which, as pointed out by my friend Mr. Children, most admirably illustrate this fact [that the valves of certain bivalves may occasionally be reversed]; for the valves, being unequally convex, if the two shells are placed on their most convex valves, their beaks turn toward each other, as the mouths of reversed and regular spiral univalves would do if placed on their backs." A footnote adds: "I call this new shell *Lucina Childrinae* [*sic*, err. pro *L. childrenae*]; it is distinguished from all other Lucinae by being unequivalved, and approaching nearly in form to the Cytherea exuleta; there is also another specimen in the British Museum."

It clearly was this "other specimen" that was the subject of the formal description of the species published in the Annals of Philosophy in 1825, for in his letter of transmittal of his manuscript Gray states: "In the following list I have . . . described some new [species] that are contained in the collection in the British Museum, where most of the species are exhibited with the names, here adopted, attached." This specimen, which was in the collections bequeathed to the British Museum in 1799 by the Rev. C. M. Cracherode, has been selected and figured as the lectotype of the species by Wilkins (1957, p. 159, pl. 23, fig. 6). According to Wilkins it has not proved possible to trace the specimens that were in the Tankerville collection.

Wilkins does not give the dimensions of the lectotype specimen. His illustration (pl. 23, fig. 6), said to be of natural size has

[7] It may be noted in passing that Sowerby's erroneous citation apparently was uncritically accepted by Carpenter (1864, p. 522) who states: "*Lucina Childreni* [described by Gray in Ann. Phil. 1824; v. also Zool. Jour. vol. i, 1825, pp. 221-2. . . . ]" and perpetuated by Dall (1903, p. 1377).

the left valve in front of, and partially superimposed upon the right, so that the latter cannot be accurately measured. The dimensions of the left, apparently less inflated, valve as measured from the figure are: height 87.8 mm, length 83 mm.

Gray's first notice of the species in the Zoölogical Journal is quoted above. His formal description, in the Annals of Philosophy, was as follows:

"LUCINA *Childrenae*.[8] Testa suborbiculata inequivalvis alba subantiquata; tenuissime radiata substriata: long. 3 unc. Brazil, *Humphreys.* nob. *Zool. Jour.* i. 221."

The first adequate description was given by Reeve in the Conchologia Iconica, "*Lucina*" (1850, pl. 3, sp. 12):

"Shell rather large, elliptically orbicular, attenuated towards the umboes, inequilateral, flexuously angled posteriorly, one valve flat, the other convex, very thickly striated concentrically, decussated with numerous fine impressed radiating striae, central teeth of the hinge two in number, prominent, divaricate, lateral teeth callus, nearly obsolete; white within and without.

"Hab. Brazil.

"In this fine species sometimes the right valve, sometimes the left is the flat one, the opposite valve in either case being convex."

The statement that the "central teeth of the hinge two in number [are] . . . divaricate" does not accord with the condition of these teeth in the hinges here available for study. As previously noted, the left anterior and the right posterior cardinals are divaricate but the right anterior and left posterior teeth are simple and lamellar. It may be that Reeve interpreted the projecting edge of the small lunule in the right valve as one segment of a bifid tooth, but there is no corresponding structure adjacent to the left posterior cardinal that could be so misconstrued. His excellent figure of the hinge of this valve does show what appears to be an imperfection or shell fragment lodged against the ventral portion of the anterior side of this tooth, but it is difficult to understand how this could be construed as a segment of a bifid tooth.

The general characters of *M. childrenae* have been noted in the general discussion of the genus *Miltha.* The most distinctive feature for the recognition of this species is to be found in the nature of the lunular area and the adjacent right anterior cardinal tooth. As noted above (page 100), the lunule is but little impressed below and is almost parallel with the anterior dorsal margin of the valve, making an angle of approximately 65° with the valve height. In the other species here studied the lunule has a much more vertical trend, usually lying at an angle of less than 40° from the vertical. As a result of this less steeply impressed condition the lunule has had but little dynamic effect upon the right anterior cardinal which, while closely adjacent to it, appears to be distinctly separated throughout its entire length; in the other species the dorsal portion of this tooth either becomes fused on its anterior side with the lunular margin or, as in *M. caloosaensis*, is practically incorporated into the lunule itself.

It may also be noted that the antero-ventral margin of the elongate anterior adductor scar is on the whole more nearly parallel with, and relatively somewhat closer to, the adjacent portion of the pallial line

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[8] It is to be observed that in both of his citations Gray gave his specific name a female termination, apparently naming it in honor of Miss Anna Children, daughter of his "friend Mr. [J. G.] Children," at that time Assistant Keeper of the Natural History Department of the Museum, whom he credited, in the Zoological Journal, as calling it to his attention. Miss Children had been engaged in the British Museum in making drawings of specimens from that collection to illustrate her father's well known "Lamarck's Genera of Shells translated from the French, with plates from original drawings by Miss Anna Children" published in the Quarterly Journal of Science, Literature and Arts, 1822-24.

Dr. Leo G. Hertlein of the California Academy of Sciences has called to my attention a page of "errata" that follows the index to volume one of the Zoological Journal. This contains the statement, "for *childrinae*, read *childreni.*" The index was published in part four of the volume that bears the date of January, 1825 on the table of contents. In view of the fact, noted above, that the paper containing the formal description of the species published in the Annals of Philosophy bears the notation "British Museum, Jan. 10, 1825," it seems almost certain that the errata in the Zoological Journal was prepared by an editor without being approved by the author.

This consistent usage by Gray was overlooked or ignored by contemporary (Sowerby, 1825, 1826; Wood, 1828) and subsequent (Reeve, 1850, H. & A. Adams, 1858, Carpenter, 1864; Dall, 1901, 1903, 1905; etc.) authors, all of whom used the masculine termination, "*Childreni.*"

than it is in the other species here studied. There is, however, a considerable degree of variation in this feature, even between opposite valves of the same specimen, and some specimens of *M. caloosaensis*, especially, are identical in this respect, although on the average they tend to be less strikingly parallel with the pallial margin than is the average of the available specimens of *M. childrenae*.

Early authors have simply cited this species as from "Brazil." The first more specific locality citation of which I am aware is given by Dall (1905, p. 111), who stated that his shell "was recently collected at Pernambuco." The U. S. Fish and Wildlife Service, M/V *Oregon*, collected the specimens here examined at Station 4228, Latitude 20°02′ South, Longitude 43°17′ West, 28 fathoms, bottom temperature 84°F. This locality is off Sao Luís, Est. Maranhão, more than 800 miles northwestward along the coast from Recife, the capital city of Pernambuco. If Dall's more generalized locality was precise, the species is much more widely distributed than its rarity in collections would suggest.[9]

*Figured specimen*: USNM 679267-A, height 86.2 mm, length 76.6 mm, diameter (right valve, less inflated) 10 mm. *Oregon* stn. 4228.

*Figured specimen*: USNM 679267-B, height 58.3 mm, length 54.8 mm, diameter (right valve, inflated) 9.8 mm. *Oregon* stn. 4228.

*Figured specimen*: USNM 679267-C, height 30.5 mm, length 28.8 mm, diameter (left valve, inflated) 5.2 mm. *Oregon* stn. 4228.

## VI. Species of Miltha s.s. from the Neogene Deposits of Southern Florida

### Miltha (Miltha) chipolana (Dall)

Plate 1, Figure 3; Plate 2, Figures 4a, b; Plate 3, Figures 1a-d, 2a-d; Plate 5, Figures 1-6; Text Figure 1

1903, *Phacoides* (*Miltha*) *chipolanus* Dall, Trans. Wagner Free Inst. Sci., vol. 3, pt. 6, p. 1375, pl. 51, fig. 11.

1903, *Phacoides* (*Miltha*) *heracleus* Dall, Trans. Wagner Free Inst. Sci., vol. 3, pt. 6, p. 1376, pl. 51, fig. 10.

1917, *Phacoides* (*Miltha*) *Smithwoodwardi* Maury, Bulls. Amer. Paleontology, vol. 5, no. 29, p. 368, pl. 61 (no. 29, pl. 35), fig. 6.

1920, [?] *Phacoides* (*Miltha*) cf. *smithwoodwardi* Maury. Maury, Sci. Surv. Porto Rico and Virgin Islands, vol. 3, pt. 1, p. 33.

1926, *Phacoides* (*Miltha*) *chipolanus* Dall. Gardner, U. S. Geol. Surv., Prof. Pap. 142C, p. 110, pl. 19, figs. 3-6 [*heracleus* Dall placed in synonymy].

1930, *Miltha* (*Miltha*) *chipolana* Dall. Stewart, Acad. Nat. Sci. Phila., Spec. Publ. 3, p. 190.

Dall's original description of this species was as follows:

"Shell large, rather thin, compressed, with small, pointed, recurved beaks, over a small, narrow, rather deeply impressed lunule; there is no anterior dorsal area; the posterior area is long, narrow, and divided into two nearly equal parts by an impressed line; sculpture of fine, slightly irregular concentric raised threads, stronger distally, sublamellose on the dorsal area, fainter in the middle of the disk, and rather close-set; radial sculpture of faint, obscure, slightly vermicular markings, hardly visible except in the middle of the disk; anterior adductor scar elongate; posterior short, ovate; cardinal teeth well developed; ligament short, deeply insert. Alt. 75, lon. 71, diam. about 11 mm.

"The figure of this species is restored from a number of fragments which give practically

[9] After this manuscript had been submitted for publication, Dr. A. Myra Keen informed me that there were, in the Stanford University collections, four valves collected by Mr. Donald Bryant from beach drift in Todos os Santos Bay, Bahia, Brazil. This locality is more than 400 miles south of Recife, and indicates a distribution along more than 1200 miles of the Brazilian coast.

→

Plate 7

*Miltha* (*Miltha*) *carmenae* H. E. Vokes, new species ..... 122

Figs. 1-4. Holotype, USNM 646409, height 82.7 mm, length 76.5 mm, diameter (paired valves) 20.4 mm. 1, exterior of more inflated left valve; 2, dorsal view of paired valves, note manner in which anterior dorsal margin of flatter right valve displaces margin of the left; 3, 4, exterior and interior views of right valve of lesser convexity. Locality TU 201.

Fig. 5. Paratype, USNM 646411, height 62.5 mm, length 58.7 mm. View of hinge (× 1.7) of smaller right valve with lunular margin more deeply impressed than usual in the species, and approaching condition characteristic of *Miltha caloosaensis* (Dall).

Figures 1 to 4 approximately natural size.

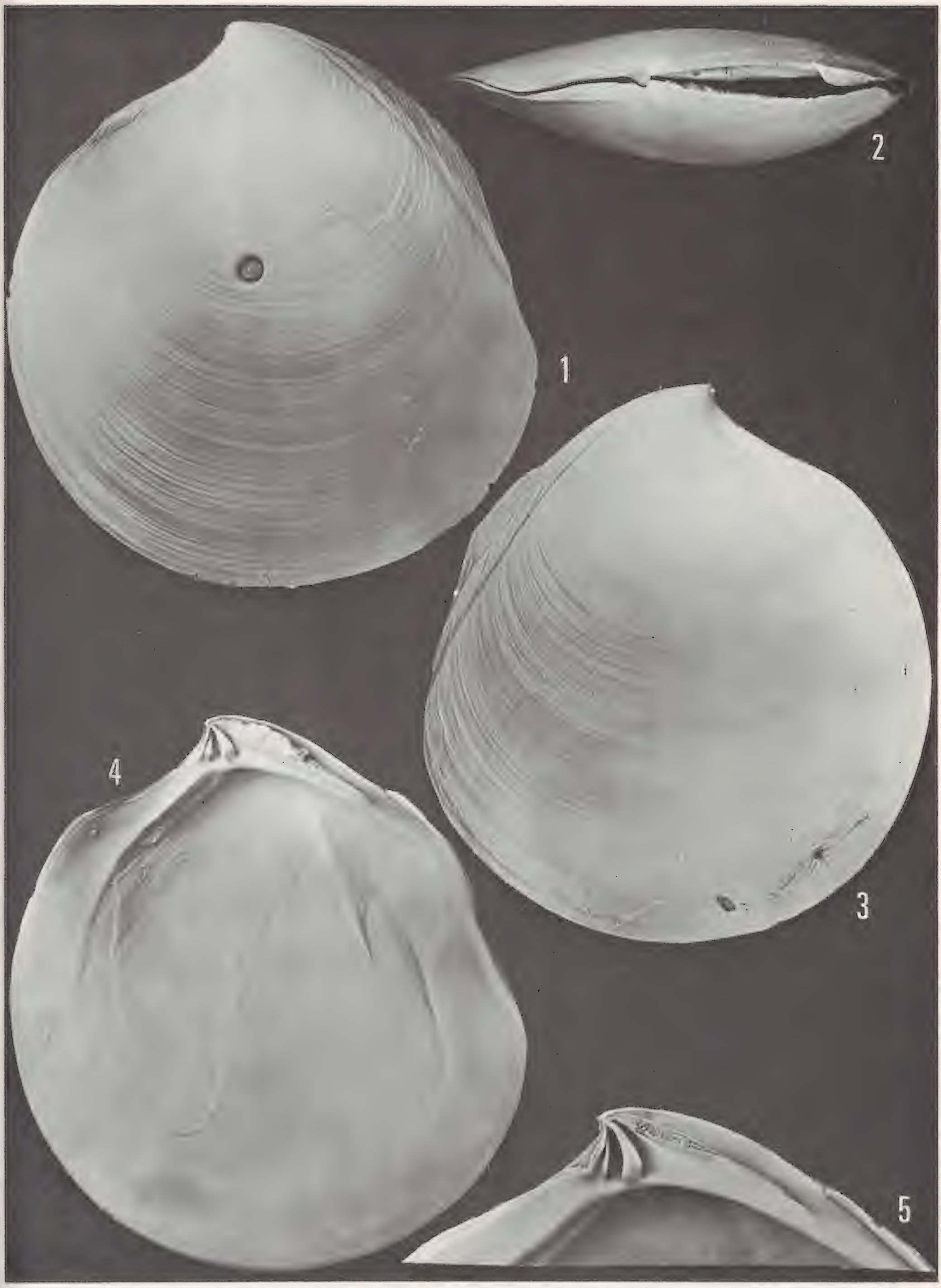



PLATE 7

all the characters except the hinge of the left valve. It is a large, very compressed form . . . "

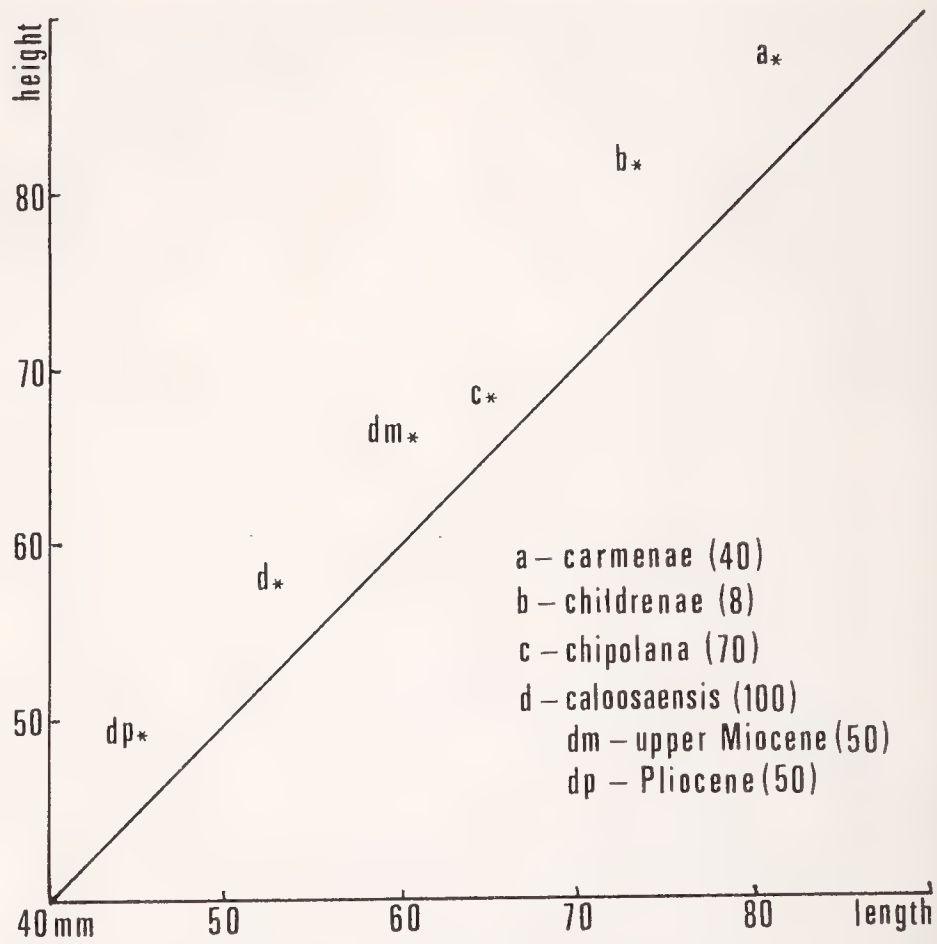
Dall's reference to the species as being "very compressed" and his measurements indicating a diameter of "about 11 mm." in a shell of 75 mm altitude, rather clearly indicate that he had only the flatter, less inflated valves of this species. He did not recognize that the right valve from Alum Bluff, Florida, which he made the type of his new species *heracleus*, actually was the inflated valve of the form that he had just described as *chipolanus*. The Alum Bluff *heracleus* was described as follows:

"Shell large, convex, subequilateral, rather thick, with small, pointed, prosogyrate beaks over an arcuately impressed, small, sublanceolate lunule; anterior dorsal area narrow and rather short, defined by a shallow sulcus; posterior area narrow elongate, divided by a second longitudinal sulcus into two parts, of which the anterior is wider; sculpture of fine concentric lines, feebler in the middle of the disk, and of faint, nearly obsolete, sparser radial striations; ligament deeply inset, rather long; cardinals normal, rather small and slender. Alt. 80, lat. 77, diam. 30 mm.

" . . . Only one right valve and a fragment have so far been obtained."

In many ways *Miltha chipolana* is the most variable of the species here studied. In general the valves are slightly higher than long; the length in 50 specimens measured, averaging 95% of the height but varying from slightly less than 84% in the relatively highest form to 109% in the relatively longest. Figures 1 and 4 on plate 5, represents a specimen of average height—length proportions (text fig. 3), while figure 6 on the same plate is one of the more elongate forms. This variation is not a function of differing proportions during growth; the relatively highest specimen measured has a height of 49.3 mm and a length of 41.3 mm, while the longest has a height of 45.5 mm and a length of 49.6 mm.

Concentric surface ornamentation is similar to that found on all of the species studied, and the same weak tangential lineation of minute raised threads is present. The radial ribbing is, on the whole, more variable than in the other species, perhaps a little more strongly developed than that on *M. carmenae*, but with the majority of the ribs being much narrower. However, there is an apparent tendency toward variation in this feature and occasional ribs will be two to three times the width of those adjacent.




Text figure 3. Average height-length proportions of adult specimens of the species of *Miltha* examined during this study. The number in parenthesis represents the number of measurements averaged for each species.

The shape and trend of the anterior dorsal margin is, perhaps, the most variable feature of the species. In almost all specimens this margin has an almost straight outline, sloping away from the usually low and inconspicuous umbones. The slope of this margin relative to the vertical of the height of the shell varied, among the 25 specimens measured, from 67° to 80°. The majority of the specimens from the stratigraphically lower localities tend to have a somewhat steeper slope, averaging around 62° to 65°, while an ecotype or variety that occurs with forms of typical slope angle, mainly in the stratigraphically higher beds, has a margin that trends almost horizontally and is sharply subangulate at its anterior end (pl. 5, fig. 5). The figure given by Maury (1917, pl. 61, fig. 6) of her *Phacoides* (*Miltha*) *smithwoodwardi* from the Cercado Formation of the Dominican Republic, suggests a specimen that approaches this latter form. Miss Maury compared her specimen with *M. caloosaensis*, but not with *M. chipolana*, of which it is here held to be a synonym.

*Figured specimen*: USNM 646394, height 72.6 mm, length 67.6 mm, diameter (paired valves) 20.7 mm (right valve 14.2 mm, left valve, 7.5 mm). Locality TU 555.

*Figured specimen*: USNM 646395, height 64.2 mm, length 59 mm, diameter (paired valves) 15.8 mm (right valve 9.1 mm, left valve 6.8 mm.). Locality TU 459.

*Figured specimen*: USNM 646396, height 82.9 mm, length 81 mm, diameter (right valve of lesser convexity) 9.1 mm. Locality TU 820b.
*Figured specimen*: USNM 646397, height 46.6 mm, length 42.5 mm, diameter (left valve of lesser convexity) 5.5 mm. Locality TU 549.
*Figured specimen*: USNM 646398, height 44.4 mm, length 42.2 mm, diameter (convex right valve) 7 mm. Locality TU 549.
*Figured specimen*: USNM 646399, height 4.2 mm, length 3.6 mm, right valve. Locality TU 555.
*Figured specimen*: USNM 646400, height 4.3 mm, length 4.1 mm, right valve. Locality TU 555.
*Figured specimen*: USNM 646401, height 7.8 mm, length 6.8 mm, right valve. Locality TU 555.
*Figured specimen*: USNM 646402, height 11.5 mm, length 11.2 mm, right valve. Locality TU 555.
*Figured specimen*: USNM 646403, height 3.2 mm, length 3.1 mm, left valve. Locality TU 555.
*Figured specimen*: USNM 646404, height 4.4 mm, length 3.8 mm, left valve. Locality TU 555.
*Figured specimen*: USNM 646405, height 8.1 mm, length 7.5 mm, left valve. Locality TU 555.
*Figured specimen*: USNM 646406, height 10.5 mm, length 9.9 mm, left valve. Locality TU 555.

Distribution:

Tulane University localities 70, 196, 453, 458, 459, 546, 547, 548, 549, 555, 655, 820b, 821, 824, 825, 826, 827, 950, 998, 999.

## MILTHA (MILTHA) CALOOSAENSIS (Dall)

Plate 1, Figure 4; Plate 2, Figures 3a, b; Plate 6, figs. 1-5

1898, *Lucina* (*Miltha*) *caloosaënsis* DALL, Trans. Wagner Free Inst. Sci., vol. 3, pt. 4, p. 923, pl. 28, fig. 1.
1903, *Phacoides* (*Miltha*) *caloosaënsis* Dall. DALL, Trans. Wagner Free Inst. Sci., vol. 3, pt. 6, p. 1376.
1905, *P.* [*Phacoides*] *caloosana* [*sic*] Dall. DALL, Nautilus, vol. 18, no. 10, p. 112.
1953, *Miltha* (*Miltha*) *caloosaënsis* (Dall). OLSSON and HARBISON, Acad. Nat. Sci. Phila., Mon. 8, p. 89 [part].
1958, *Miltha* (*Miltha*) *caloosaensis* (Dall). DUBAR, Florida Geol. Surv., Geol. Bull. 40, p. 169.

This species was originally named, with an illustration only, by Dall in 1898, but the description did not appear until 1903:

"Shell elevated, rather compressed, short, finely concentrically striated; beaks small, pointed, slightly curved forward over an exceedingly minute and almost obsolete lunule; anterior dorsal area short, narrow, feebly defined; posterior area long, wider, defined by a narrow sulcus, with a less pronounced sulcation dividing the area lengthwise into nearly equal parts; there are traces of very minute radial striation on some specimens; resilium shorter than the ligament, both deeply insert and partly covered by the dorsal margin, which is usually broken away; teeth and scars normal, well developed; disk internally with a well-marked oblique sulcus. Alt. 53.0 (to 63.0), lon. 47.0, diam. 13.5 mm.

"The lunule is better developed in the older specimens and more in the right than in the left valve. Some specimens have the right valve less convex than the left. The species is very like *P.* (*Miltha*) *Childreni* Gray [*xantusi* Dall], but is proportionately more elevated, with a more delicate hinge and smaller muscular impressions. . . ."

The original figure gave no locality information beyond the geologic age, "Pliocene;" the 1903 description added: "Pliocene of the Caloosahatchee and Shell Creek, Florida." While this species has in the past been thought to be restricted to the Caloosahatchee Formation (DuBar, 1958, p. 169, Olsson and Petit, 1964, p. 520), Tulane University collections reveal that it is rather widely distributed in the upper Miocene Pinecrest beds of southern Florida. The Caloosahatchee specimens are in general smaller than those from the Miocene. The average dimensions of 50 of the larger Caloosahatchee specimens in the Tulane collections are: height 49.4 mm, length 45.4 mm; the largest is 65.2 mm high and 61 mm long. The average dimensions of 50 upper Miocene specimens are: height 65.8 mm, length 60.8 mm; the largest being 92.1 mm high and 81.4 mm long.

*Miltha caloosaensis* is the smallest of the species of *Miltha* here being considered (text fig. 3). Although the upper Miocene specimens average almost as large as *M. chipolana*, the Pliocene specimens average approximately 20 mm shorter and narrower than that species. Compared with other Florida Tertiary species *M. caloosaensis* is more regularly elongate-ovate in form with lower, less prominent umbones and shorter and, usually, more rounded anterior dorsal margin. In these features it is similar to the Recent *M. childrenae*, from which it may be distinguished, as from the other Florida Tertiary species, by the deeply impressed, concave lunule in the right valve, the anterior portion of which trends almost vertically and is closely appressed against the dorsal part of the anterior cardinal tooth, which becomes so reduced, especially in

its height, as to be almost obliterated. The corresponding area of the left valve is particularly marked by the fact that the low lamellar ridge separating the incised area for the reception of the lunular margin from the anterior cardinal socket trends across the socket towards its dorsal end and becomes appressed against the side of the bifid left anterior cardinal tooth. A somewhat similar situation is occasionally present in the variable *M. chipolana*, but these specimens may be distinguished by the fact that the ridge separating the lunular area from the anterior cardinal socket in the left valve is never as high and lamellar in shape, and the depressed area for the reception of the lunular margin is narrower, usually only about one-half as wide as it is in specimens of *caloosaensis* of the same relative size.

*Figured specimen*: USNM 646407, height 61.9 mm, length 55.5 mm, diameter (paired valves) 15.4 mm—(right valve, 9.3 mm, left valve 6.8 mm; the left fitting slightly inside the right). Locality TU 796 (upper Miocene).

*Figured specimen*: USNM 646408, height 55.2 mm, length 49.8 mm, diameter (paired valves) 14.2 mm (right valve 7.8 mm, left valve, 6.5 mm). Locality TU 755 (Pliocene).

Distribution:

Caloosahatchee Formation, Pliocene: Tulane University localities 79, 519, 536, 539b, 579, 583, 755, 768, 974, 975, 980.

Pinecrest beds, upper Miocene: Tulane University localities 520, 540, 728, 729, 730, 736, 740, 741, 742, 756, 769, 796, 797, 933, 979, 981, 982, 985, 1000.

## Miltha (Miltha) carmenae
## H. E. Vokes, new species

Plate 1, Figure 2; Plate 2, Figures 2a, b; Plate 6, Figure 4; Plate 7, Figures 1-5

1953, *Miltha* (*Miltha*) *caloosaënsis* (Dall). Olsson and Harbison, Acad. Nat. Sci. Phila., Mon. 8, p. 89 (in part—"large specimens . . . from Clewiston and Belle Glade").

1964, "*Miltha* sp. (large)," Olsson and Petit, Bulls. Amer. Paleontology, vol. 47, no. 217, p. 521.

*Description*: Shell large for the genus, subcircular in outline with moderately prominent concentric and exceedingly weak radial ornamentation, the latter visible only under strongly oblique lighting. Valves unequally inflated. Umbones high, prominent; posterior dorsal slope broadly convex, descending at an angle of approximately 55° from the vertical; posterior margin almost straight, sloping postero-ventrally; postero-ventral margin relatively sharply rounded into the broadly and equally convex ventral and anterior margins; anterior dorsal margin concave immediately below and in front of the umbones, becoming straight for a short distance before rounding into the anterior margin, the angle from the umbo to the anterior end of the margin being approximately 65° from the vertical of the valve height. Anterior dorsal area almost not delimited in the flatter valves, with only a very obscure margining groove, but with a strong tendency in the larger specimens to curve laterally against, and somewhat to displace the anterior end of the dorsal area of the more inflated valve; anterior dorsal area of inflated valves with a broad marginal rib that becomes enlarged and prominent in the area of displacement by the less inflated valve. Posterior dorsal areas well-marked, long, with a deep marginal groove but with the dorsally adjacent rib always low, broad and inconspicuous, so there is no suggestion of a second "medial" groove on the area.

Hinge plate broad, usually with a narrow, raised rib on its anterior ventral edge. Cardinal teeth two in each valve, the left anterior and the right posterior relatively broad and obscurely bifid, the right anterior and left posterior simple; all teeth arcuate with their anterior faces broadly concave. Lunule small, deeply impressed and confined to the right valve, marked more or less like the postero-dorsal area with a strong groove separating the lunular surface from the rather corrugated edge of the impressed area of the valve, and with an adjacent ill-defined ridge that passes rather gradually into a more depressed flattened area near the inner margin of the lunule. The posterior (inner) face of the lunule is closely appressed against the right anterior cardinal but separated from it by a shallow groove, such that the projecting edge of the lunule and the top of the cardinal have the appearance of a single rather deeply bifid tooth. Ligament and nymph plate typical of the genus.

Pallial line distant from the valve margin, entire, relatively wide and impressed, its surface marked by irregularly spaced low ridges that appear almost as if radiating from a point a short distance below the umbones (see text fig. 2b). Anterior adductor scar long, relatively broad, its ventral face with less curvature than the pallial line so that its ventral end is more approximate to the pallial line than is its median area; posterior ventral end broadly rounded, posterior dorsal side almost straight; the surface marked by oblique, subparallel low ridges similar to those of the pallial area. Posterior adductor scar, reniform, broadly rounded ventrally, the dorsal side straight to slightly concave, the low point of the concavity situated at a groove that divides the scar into two unequal areas, the outer of which is relatively smooth, marked only by concentric lines of muscle increase, the inner with fine sub-parallel ridges similar to those on the anterior adductor and pallial line. Other internal markings as in the genus (see pp. 106-110).

Holotype: USNM 646409, height 82.7 mm, length 76.5 mm, diameter (impaired valves) 20.4 mm (right valve, 12.3 mm, left valve, 8.2 mm). Locality TU 201.

Paratype: USNM 646410, height 105.5 mm, length 98.8 mm, diameter (left valve of lesser convexity) 9 mm. Locality TU 201.

Paratype: USNM 646411, height 62.5 mm, length 58.7 mm, diameter (right valve of lesser convexity) 6.4 mm. Locality TU 978.

Distribution:

Tulane University localities 201, 727, 731, 978, 987, 988.

This appears to be the largest of the known species of the genus *Miltha*, one specimen in the Hoerle collection is 127.6 mm high and 122.5 mm long; the average dimensions of the 40 adult specimens sufficiently perfect to permit accurate measurement are: height 87.0 mm, length 81.7 mm. It is probable that adequate collections of *M. childrenae* will show that species approaches *M. carmenae* in overall dimensions (text fig. 3); the average dimensions of the adult specimens in the present collection, plus those of the lectotype (see page 116) and of the specimen mentioned by Dall (1905, p. 112) are: height 81 mm, length 73.8 mm. *M. carmenae* easily may be distinguished from *M. childrenae* as well as from the other species in the Florida Neogene deposits by the relatively high umbones and the more steeply sloping dorsal margins, especially the anterior one where the rather large concavity immediately in front of the umbones accentuates their apparent elevation.

*Miltha carmenae* is moderately common in the deposits of the unnamed post-Caloosahatchee formation, "Unit A" of Olsson and Petit (1964, p. 521), in the region about Lake Okeechobee, especially to the east and southeast of the lake. The sediments and faunas from these deposits appear to suggest deposition in somewhat more off-shore waters than were the deposits from the more western outcrops of the formation.

This species is named for Carmen, the daughter of the late Mr. Thomas S. Hughes, of Fort Pierce, Florida, who appears to have been the first to recognize that it represented an undescribed species and who used this name in his manuscript field notes.

## VII. Locality Data

The following are Tulane University fossil localities:

70. Chipola Fm., Ten Mile Creek, at bridge of Florida Highway 73 (NW ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.
79. Caloosahatchee Fm. and unnamed post-Caloosahatchee formation mixed, spoil banks north and south side of Caloosahatchee River, at Ortona Lock (Sec. 27, T42S, R30E), Glades Co., Florida.
196. Chipola Fm., Ten Mile Creek, about ¼ mile upstream from bridge of Florida Highway 73 (NE ¼ Sec. 11, T1N, R10W), Calhoun Co., Florida.
201. Unnamed post-Caloosahatchee formation, spoil banks at pit just south of Belle Glade (at Belle Glade Camp), Palm Beach Co., Florida.
453. Chipola Fm., lower beds at Alum Bluff, Appalachicola River (NE ¼ Sec. 24, T1N, R8W), Liberty Co., Florida.
458. Chipola Fm., east bank of Chipola River, above Farley Creek (SW ¼ Sec. 20, T1N, R9W), Calhoun Co., Florida.
459. Chipola Fm., east bank Chipola River, steep bank about 1500 ft. above mouth of Taylor Lake Branch (NW ¼ Sec. 29, T1N, R9W), Calhoun Co., Florida.
519. Caloosahatchee Fm., Harney Pond Canal spoil banks, at Florida Highway 78, northwest side of Lake Okeechobee (NW ¼ Sec. 18, T40S, R33E), Glades Co., Florida.
520. Pinecrest beds, spoil banks, canal 0.9 mile east of Brighton on Florida Highway 70 (Sec. 25, T37S, R32E), Highlands Co., Florida.
536. Caloosahatchee Fm., south bank of Caloosahatchee River about one mile east of La Belle (Sec. 3 & 4, T43S, R29E), Hendry Co., Florida. (Designated as type locality of the Caloosahatchee Formation by Olsson *in* Olsson and Petit, 1964, p. 519.)
539b. Caloosahatchee Fm., Shell Creek (lower beds), about eight miles east of Cleveland (Sec. 30, T40S, R25E), Charlotte Co., Florida.
540. Pinecrest beds, Miami Canal spoil banks, one to three miles south of pumping station at Palm Beach county line, Broward Co., Florida.
546. Chipola Fm., Ten Mile Creek, about 1½ miles west of Chipola River (NE ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.
547. Chipola Fm., west bank of Chipola River, about 2000 ft. above the mouth of Four Mile Creek (SW ¼ Sec. 29, T1N, R9W), Calhoun Co., Florida.
548. Chipola Fm., west bank of Chipola River (NW ¼ Sec. 29, T1N, R9W), Calhoun Co., Florida.
549. Chipola Fm., east bank of Chipola River, about ¼ mile below Four Mile Creek (NE ¼ Sec. 32, T1N, R9W), Calhoun Co., Florida.
555. Chipola Fm., east bank of Chipola River, about 1000 ft. above the mouth of Four Mile Creek (SW ¼ Sec. 29, T1N, R9W), Calhoun Co., Florida.
579. Caloosahatchee Fm., Miami Canal spoil banks, four miles north of pumping station

at Broward county line, Palm Beach Co., Florida.
583. Caloosahatchee Fm., Miami Canal spoil banks, seven miles north of pumping station at Broward county line, Palm Beach Co., Florida.
655. Chipola Fm., Ten Mile Creek, about 0.1 mile downstream from bridge of Florida Highway 73 (NW ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.
727. Unnamed post-Caloosahatchee formation, borrow pits 2.2 miles east of U. S. Highway 27, 15 miles south of South Bay, Palm Beach Co., Florida.
728. Pinecrest beds, spoil banks on west side of Kissimmee Canal and east side of Kissimmee River, just across from U. S. Corps of Engineers Structure 65-D (Sec. 33, T36S, R33E), Okeechobee Co., Florida.
729. Pinecrest beds, spoil banks on west side of Kissimmee Canal and east side of Kissimmee River, approximately ½ mile south of U. S. Corps of Engineers Structure 65-D (S ½ Sec. 33, T36S, R33E), Okeechobee Co., Florida.
730. Pinecrest beds, embankment of Seaboard Airline Railroad, just west of Kissimmee River (NW ¼ Sec. 20, T36S, R33E), Highlands Co., Florida.
731. Unnamed post-Caloosahatchee formation, West Palm Beach Canal spoil banks, at junction of U. S. Highways 441 and 98, seven miles west of Loxahatchee, Palm Beach Co., Florida.
736. Pinecrest beds, spoil banks on south side of Florida Highway 70 and east side of Kissimmee River, Okeechobee Co., Florida.
740. Pinecrest beds, levee fill, L-28, 3.6 miles west and 2.6 miles south of pumping station on Miami Canal at Broward-Palm Beach county line, Broward Co., Florida.
741. Pinecrest beds, levee fill, L-28, 3.6 miles west and 3.6 miles south of pumping station on Miami Canal at Palm Beach county line, Broward Co., Florida.
742. Pinecrest beds, levee fill, L-28, 3.6 miles west and 5.6 miles south of pumping station on Miami Canal at Broward-Palm Beach county line, Broward Co., Florida.
755. Caloosahatchee Fm., Miami Canal spoil banks, 17.4 miles north of pumping station at Broward county line, Palm Beach Co., Florida.
756. Pinecrest beds, spoil banks west side of Elkcan Waterway, Port Charlotte Development, 2.3 miles southeast of Port Charlotte Railroad Station (formerly Murdock) and 1.7 miles east of U. S. Highway 41 (Sec. 10, T40S, R22E), Charlotte Co., Florida.
768. Caloosahatchee Fm. and unnamed post-Caloosahatchee formation mixed, spoil banks north side of Caloosahatchee River, 5½ miles west of Ortona Lock (NW ¼ Sec. 35, T42S, R29E), Glades Co., Florida.
769. Pinecrest beds, spoil banks east side of Kissimmee River, 1½ to two miles south of U. S. Corps of Engineers Structure 65-D (NE ¼ Sec. 35, T36S, R33E), Okeechobee Co., Florida.
796. Pinecrest beds, material exposed during construction of "Alligator Alley," 12.8 miles east of Florida Highway 29 (T49S, R32E), Collier Co., Florida.
797. Pinecrest beds, material exposed during construction of "Alligator Alley," 13.3 miles east of Florida Highway 29 (T49S, R32E), Collier Co., Florida.
820B. Chipola Fm., Farley Creek (lower beds), at bridge of Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.
821. Chipola Fm., Farley Creek, 0.1 mile east of bridge of Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.
824. Chipola Fm., Farley Creek, about ½ mile upstream from bridge of Florida Highway 275 (SE ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.
825. Chipola Fm., Farley Creek, at abandoned mill about ¼ mile west of bridge of Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.
826. Chipola Fm., Farley Creek, about 0.1 mile west of abandoned mill which is ¼ mile west of bridge of Florida Highway 275 (on section line between Sec. 20 & 21, T1N, R9W), Calhoun Co., Florida.
827. Chipola Fm., Farley Creek, about ½ mile west of bridge of Florida Highway 275 (SE ¼ Sec. 20, T1N, R9W), Calhoun Co., Florida.
933. Pinecrest beds, material exposed during construction of "Alligator Alley," 21.5 miles east of Florida Highway 29, Collier Co., Florida.
950. Chipola Fm., Chipola River, west bank about 2000 ft. above the mouth of Farley Creek (SW ¼ Sec. 20, T1N, R9W), Calhoun Co., Florida.
974. Pinecrest beds, north side Caloosahatchee Canal, 2½ to 3½ miles west of center of former Lake Hicpochee (now drained) (unmapped area, T42S, R32E), Glades Co., Florida.
975. Caloosahatchee Fm., spoil banks, north side Caloosahatchee Canal, 0-½ mile west of center of former Lake Hicpochee (now drained) (unmapped area, T42S, R32E), Glades Co., Florida.
978. Unnamed post-Caloosahatchee formation, spoil banks at pit on south side of waterworks, about 1½ miles northeast of South Bay, Palm Beach Co., Florida.
979. Pinecrest beds, Port Charlotte Development, spoil banks just north of Seaboard Railroad, two miles north of U. S. Highway 41, on canal 1½ miles southwest of junction with Florida Highway 771 (Sec. 4, T40S, R22E), Charlotte Co., Florida.
980. Caloosahatchee Fm., Port Charlotte Development, spoil banks on north side U. S. Highway 41, on canal 3.3 miles northwest of Florida Highway 771 (Sec. 3, T40S, R21E), Charlotte Co., Florida.
981. Pinecrest beds, Port Charlotte Development, spoil banks on south side of U. S. Highway 41, on canal 3.3 miles northwest

of Florida Highway 771 (Sec. 3, T40S, R21E), Charlotte Co., Florida.

982. Pinecrest beds, Port Charlotte Development, spoil banks on northwest side of Florida Highway 771, on canal 3½ miles southwest of junction with U. S. Highway 41 (Sec. 15, T40S, R21E), Charlotte Co., Florida.

984. Pinecrest beds, Port Charlotte Development, spoil banks 0.8 mile south of Florida Highway 771, on canal 1.9 miles southwest of junction with U. S. Highway 41 (Sec. 14, T40S, R21E), Charlotte Co., Florida.

985. Pinecrest beds, Port Charlotte Development, spoil banks about ½ mile northeast of Florida Highway 771, on U-shaped canal 3.3 miles southwest of junction of U. S. Highway 41 (Sec. 10, T40S, R21E), Charlotte Co., Florida.

987. Unnamed post-Caloosahatchee formation, spoil banks south side West Palm Beach Canal, at Loxahatchee, on U. S. Highway 98, Palm Beach Co., Florida.

988. Unnamed post-Caloosahatchee formation, spoil banks, West Palm Beach Canal at Twenty Mile Bend Recreation Area, about one mile east of junction of U. S. Highways 98 and 441, Palm Beach Co., Florida.

998. Chipola Fm., bank of Ten Mile Creek about 1¼ miles west of Chipola River (SE ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.

999. Chipola Fm., Farley Creek, about 900 feet downstream from bridge of Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.

1000. Pinecrest beds, borrow pit at east end of 17th Street, 3.2 miles east of Tuttle Road, about 8 miles east of U. S. Highway 301 in Sarasota (T36S, R19E), Sarasota Co., Florida.

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# NOTES ON THE FAUNA OF THE CHIPOLA FORMATION—I A NEW SPECIES OF *EOMILTHA* (MOLLUSCA: BIVALVIA)

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While engaged in the study of the species of *Miltha s.s.* from the Neogene deposits of Florida I noted the presence in collections from the Chipola Formation of an undescribed species of the genus *Eomiltha.* This form, which is rather rare, represents the first record of the genus in the faunas from the type area of the formation, although Gardner described (1926, U. S. Geol. Surv. Prof. Paper 142-C, p. 112, pl. 20, figs. 1, 2), as "*Phacoides* (*Miltha*)" *xustris*, a form that is to be referred to *Eomiltha* from the lower beds exposed at Alum Bluff, Liberty County, Florida. At that locality (= TU 453) about ten feet of the uppermost beds of the Chipola Formation are exposed during low water stages of the Apalachicola River. The present species is found at localities that occur approximately at the top of the basal third of the section in the type area; it thus is believed to be stratigraphically lower and hence somewhat older than *E. xustris*.

## Genus EOMILTHA Cossmann, 1912

*Eomiltha* Cossmann, 1912, Act. Soc. linn. Bordeaux, vol. 65, p. 269 [issued separately as: Cossmann and Peyrot, Conch. Néog. de l'Aquitaine, v. 1, livr. 3, p. 650, 1912].

Type species, by original designation, *Lucina contorta* Defrance, Thanetian Stage, Paleo-

cene, France. [Fig'd., Cossmann and Pissarro, 1906, pl. 24, sp. 82-8.]

The genus *Eomiltha* appears to range from the Paleocene to the Recent (*Lucina voorhoevei* Deshayes, 1857, Journ. de Conchyl., vol. 6, p. 106, pl. 2, fig. 1, from the Mozambique Channel off East Africa.) It is present in the Eocene of the Gulf Coast —"*Lucina*" *pandata* Conrad from the Gosport Sand, Upper Claibornian, and casts of an undescribed species in our collections from the Inglis member of the Moodys Branch Formation from the new Florida Cross-state Barge Canal—and of California —"*Dosinia*" *gyrata* Gabb, from the Domengine (?) Stage, at Martinez. The genus has not been recognized in post-Chipola faunas from the eastern United States.

The following discussion comparing the essential shell characters of the genus *Eomiltha* with those noted in the preceding paper for *Miltha s.s.* is based, in-so-far as the former genus is concerned, upon the 18 available specimens of *E. scolaroi*, new species, and almost 100 valves of *E. pandata* (Conrad) from the Gosport Sand at Claiborne Bluff, Monroe County (loc. TU 78), and Little Stave Creek, Clarke County (loc. TU 306), Alabama, supplemented by illustrations of the type species.

Species of *Eomiltha* may be distinguished from those referred to *Miltha s.s.* by their equally inflated valves of more elongate shape with, usually, somewhat irregular ventral outline. The surface of the valves is ornamented by irregular, raised concentric lamellae that are most strongly developed toward the anterior and posterior ends of the valves. As in *Miltha*, there is an underlying weak radial ornamentation, both the irregular radial ribbing and the sub-parallel anastomosing grooves in the inter-lamellar areas being present. However, no trace of the minute raised threads with tangential trend can be observed. Although there is a shallow round-bottomed groove extending from the umbone to the ventral end of the short and relatively straight posterior end of the shell, there is no well-defined posterior-dorsal area of the valve such as is characteristically present in *Miltha.* The lunule is small, impressed, and lanceolate in shape, and is but slightly wider in the right valve than in the left.

The hinge, as in *Miltha*, consists of two cardinals in each valve, but the posterior cardinal, **3b**, of the right valve is much broader, more trigonal and so strongly bifid as almost to resemble two separate teeth. The anterior cardinal, **3a**, is simple, and usually somewhat truncated dorsally by an ingrowth of the lunular margin, which on some specimens also transgresses across the dorsal edge of the posterior tooth. The anterior cardinal, **2a**, of the left valve is relatively broad and is grooved at its highest ventral end, although never as markedly bifid as is the right posterior tooth. It also may be somewhat truncated by the ingrowing lunular margin. The posterior cardinal, **2b**, is thin, lamellar, and relatively straight as compared to the usual curvature of the corresponding tooth in species of *Miltha s.s.* Furthermore, the wide socket necessary for the reception of the broad right posterior cardinal has crowded it back to a position more closely adjacent to, and parallel with, the anterior end of the fibrous ligament. The latter, as in *Miltha*, is separated from and shorter than the outer lamellar ligament.

Contrary to the situation in *Miltha* where the lamellar ligament appears to have trended almost directly across from one valve to the other, being roofed over posteriorly by a thin shell lamina, which I have interpreted as a remnant of the former escutcheon, the ligament of *Eomiltha* seems rather to have had the shape of a "C-spring" or tube that was split along its ventral side. The groove for its reception is incised into the dorsal side of the nymph plate and there is a shallow, but well-defined area above it that is excavated into the inner side of the dorsal margin of the valve. Some specimens of *E. pandata* (Conrad) clearly show remnants of this ligament appressed to the excavated surface. No similar excavation was observed in species of *Miltha.*

Muscle scars, pallial line, and pallial blood vessel groove are essentially as in *Miltha* but differ in details. The anterior adductor scar is relatively narrower, more elongate, with the anterior and ventral sides almost parallel. In nearly all specimens examined its posterior ventral end lies at (*e.g. E. scolaroi*), or posterior to (*e.g., E. pandata*) the midlength of the valve. In keeping with relatively more elongate shape of the valve, it is somewhat more arcuate in shape and

its trend is much more oblique than that of *Miltha.* Most striking, perhaps, is the manner in which the anterior-dorsal end is sharply "hooked" at its junction with the pallial line until it has a distinct postero-dorsal trend.

The posterior adductor scar is very similar to that of *Miltha*, agreeing, especially in thinner-shelled specimens, in shape and surface markings. In some valves in which the inner surface within the pallial line has been thickened in characteristic lucinoid manner, there is a pronounced tendency toward the restriction of the dorsal side of the inner "fast" muscle portion of the scar, until in some extreme examples it has only about half the height of the adjacent edge of the "catch" muscle portion.

The ridge that marks the site of the area where the gill demibranch was attached to the mantle is usually rather strongly developed, passing anteriorly to the inner edge of the adductor scar and continuing until it abuts against the inner side of the pallial line. The trend of this feature, on the inner side of the valve appears to be almost wholly coincident with the trend of the shallow, rounded umbonal groove on the exterior of the valve. The ridge that marks the position of the antero-dorsal attachment of the demibranch lies in the sub-umbonal cavity under the anterior portion of the hinge-plate.

The pallial blood vessel groove is well-marked, especially in those specimens with thickened shell interior. It intersects the anterior adductor scar approximately at the posterior third of its length, and in agreement with the more oblique trend of that scar, has in its ventral portion a steeply angled to almost vertical course. Dorsally, the groove tends to turn posteriorly, either in a broadly rounded arc (fig. 9) or subangulately (fig. 8) to cross the gill attachment ridge at a position below and slightly in advance of the posterior end of the nymph plate.

It is of interest to note that although almost all of the valves show evidences of shell damage during life, especially toward the anterior ends of the valves, not one of the more than 100 valves examined had been bored by a predator.

### EOMILTHA SCOLAROI H. E. Vokes, n. sp.
Plate 1, figs. 1-7

*Description*: Shell of medium size for the genus, elongate ovate, both valves equally and moderately inflated. Umbones low, prosogyrate,

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### PLATE 1

*Eomiltha scolaroi* H. E. Vokes, n. sp. Chipola Fm., Miocene.

Figs. 1, 6. Paratype, USNM 646424, height 35.5 mm, length 41.0 mm, 1, exterior of left valve (× 1); 6, hinge (× 2). Locality TU 825.

Figs. 2, 5, 7. Holotype, USNM 646423, height 32.6 mm, length 37.6 mm, 2, exterior of right valve (× 1); 5, hinge (× 2); 7, portion of surface enlarged (× 4) to show nature of ornamentation, compare with fig. 10. Locality TU 999.

Fig. 3. Paratype, USNM 646425, height 37.3, length 46.6 mm, exterior of relatively elongate left valve (× 1). Locality TU 820B.

Fig. 4. Paratype, USNM 646426, height 39.0 mm, length 43.0 mm, diameter 14.9 mm, view of paired valves tilted obliquely to show small impressed lunule (× 1). Locality TU 999.

*Eomiltha pandata* (Conrad). Gosport Sand, Eocene.

Fig. 8. USNM 646428, height 31.3 mm, length 35.7 mm, interior of left valve (× 1). Locality TU 306.

Figs. 9, 10. USNM 646427, height 37.8 mm, length 42.8 mm, 9, interior of right valve (× 1); 10, portion of surface enlarged to show ornamentation (× 4), compare with fig. 7. Locality TU 306.

Figures 8 and 9 show two specimens in which interior of valve is thickened with extra shelly material, thus emphasizing internal structures. Note the "hooked" anterior end of the anterior adductor scar, the reduced height of the anterior segment of the posterior adductor scar, and the curved (fig. 9) to subangulate (fig. 8) bend in the dorsal segment of the pallial blood vessel groove.

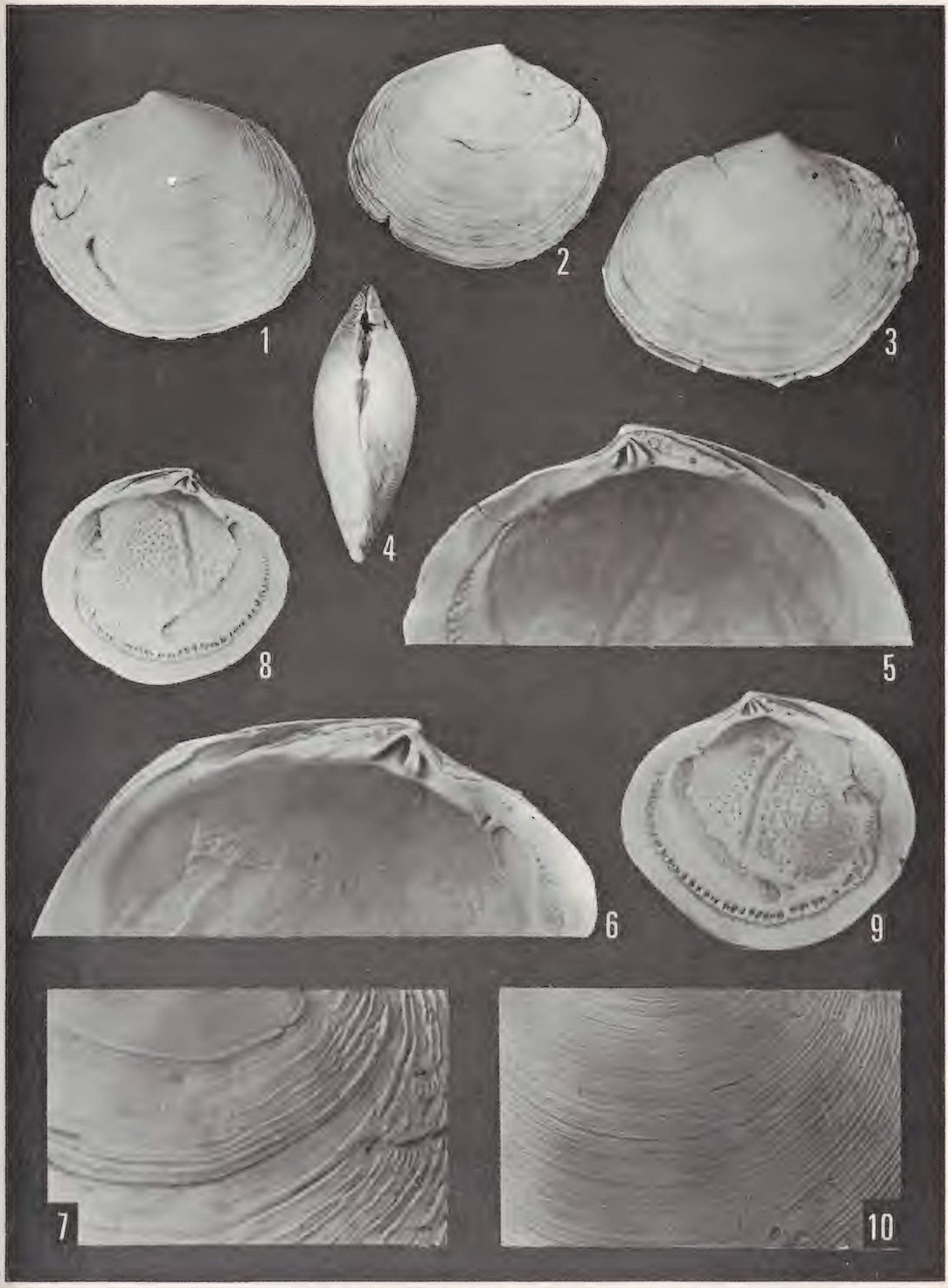


PLATE 1

situated slightly in advance of the middle and posterior to the anterior third of the total length of the valve. Anterior and ventral margins broadly and regularly rounded, the latter exhibiting little or no tendency toward the straightening of the anterior or posterior portions so characteristically found in *E. pandata*. Postero-ventral margin sharply rounded, almost subangulate to the relatively straight posterior, which slopes antero-dorsally before again bending rather sharply into the straight or very slightly convex postero-dorsal margin. Lunule relatively small, lanceolate, deeply incised in both valves and bounded by a shallow impressed line. In adult specimens the inner margin of the lunule, and occasionally also of the anterior portion of the valve immediately in front of it, grows downward onto the hinge-plate covering the dorsal ends of both cardinals in the right valve and of the anterior cardinal in the left. In no specimen examined was the left posterior cardinal covered, the shell material abutting against and stopping at its anterior dorsal side.

Surface of the valve marked by a shallow rounded posterior umbonal groove extending to the postero-ventral angulation. In some specimens a faintly developed, broad and rounded low rib parallels the posterior side of the groove, but is so weak as not to be observed on all. Ornament consisting of distant, thin, raised lamellae separated by interspaces from three to five times as wide. The lamellae are low and inconspicuous, practically absent on the median and umbonal areas of the valves, and most strongly developed toward the anterior and posterior, and to a lesser extent, the ventral margins.

Hinge as in the genus: right anterior cardinal relatively thin, lamellar, extending but slightly more than half-way across the width of the hinge-plate; right posterior cardinal strong, broadly trigonal, deeply bifid, and slightly undercut along its anterior side; left anterior cardinal relatively heavy, straight, transversing the width of the hinge plate, and grooved at its highest point, which is near its ventral termination. Left posterior cardinal thin, straight, closely adjacent to the anterior end of the fibrous segment of the ligament. The latter is seated upon a well-developed nymph that occupies approximately the lower half of the hinge-plate posterior to the cardinal tooth. The dorsal half marked by an elongate excavated area in which the outer lamellar ligament was seated. This excavation extends posteriorly beyond the end of the nymph, widening until occupying almost all of the hinge-plate. The length of this excavated area little more than one and one-half times the length of the nymph.

Muscle scars, pallial line and other internal markings as in the genus. Inner margins of the valves smooth, non-denticulated.

Holotype: USNM 646423, height 32.6 mm, length 37.6 mm, diameter (right valve) 7.0 mm. Locality TU 999.

Paratype: USNM 646424, height 35.5 mm, length 41.0 mm, diameter (left valve) 8.2 mm. Locality TU 825.

Paratype: USNM 646425, height 37.3 mm, length 46.6 mm, diameter (left valve) 8.3 mm. Locality TU 820B.

Paratype: USNM 646426, height 39.0 mm, length 43.0 mm, diameter (paired valves) 14.9 mm. Locality TU 999.

*Distribution*: Tulane University localities 459, 820B, 821, 825, 999. Complete descriptions of these localities are given in the preceding paper, as well as full references to the papers cited.

*Eomiltha scolaroi* new species, most closely resembles the Claibornian, Eocene, species *E. pandata* (Conrad) in overall aspect. It may be distinguished, however, by details of shape and surface ornamentation, especially its more regularly rounded ventral margin and straighter posterior one. The raised concentric lamellae on the surface of the valve are stronger, but more distant and irregular on the lateral portions of the valve, and much weaker on the median and umbonal areas. *Eomiltha xustris* (Gardner), known only from Alum Bluff, has a more rounded outline with less pronounced straightened posterior margin and more strongly developed concentric surface ornamentation, which is well developed on the median as well as on the lateral portions of the valves.

All but one of the specimens of *Eomiltha scolaroi* in the Tulane University collections are from a single bed of sandy, miliolid-bearing marl of a yellow-brown color, which crops out along the course of Farley Creek, a tributary of the Chipola River. The single specimen from the Chipola River section is from Tulane locality 459 where the matrix also consists of a fairly coarse quartzitic sandstone.

This species is named from Dr. Reginald J. Scolaro who, as a graduate student at Tulane University engaged in a study of the Bryozoan faunas of the Chipola Formation, first called to our attention the occurrence of fossil-bearing outcrops in the bed of Farley Creek.

The specimens of *E. scolaroi* described above were collected during the course of field studies made possible through Grant GB-6048 from the National Science Foundation. The financial assistance thus afforded is herewith gratefully acknowledged.

December 29, 1969

# SOME NEW AND STRATIGRAPHICALLY USEFUL CALCAREOUS NANNOFOSSILS OF THE CENOZOIC[1]

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## ABSTRACT

Fifteen new species of calcareous nannofossils of probable stratigraphic significance are described here. Several of these—*Cyclococcolithus macintyrei, Discoaster neohamatus, Discoaster quintatus, Helicopontosphaera sellii, Micrantholithus procerus, Sphenolithus anarrhopus, Sphenolithus neoabies, Thoracosphaera prolata,* and *Triquetrorhabdulus inversus*—are among taxa known to be abundant with wide geographic ranges and thus particularly useful in developing worldwide zonations. This usefulness has been evident during preliminary studies of Deep Sea Drilling Project cores, and naming the taxa, therefore, is important. Other new species—*Helicopontosphaera papillata, Leptodiscus larvalis, Pemma snavelyi, Quinquerhabdus colossicus, Syracosphaera formosa,* and *Syracosphaera labrosa*—are presently known only from restricted regions or constitute only a minor part of worldwide assemblages. They, too, may prove useful because they are easily identified and seem to have restricted time ranges.

[1] Publication authorized by the Director, U. S. Geological Survey

## I. INTRODUCTION

The new species of calcareous nannofossils described here can be effectively identified by light microscope and have proved to be useful in the stratigraphic interpretation of many assemblages. For example, *Thoracosphaera prolata* and *Triquetrorhabdulus inversus* are consistent indicators, on a worldwide basis, of middle Eocene strata. Within their range, other species, such as *Micrantholithus procerus* and *Syracosphaera labrosa,* help to delimit upper middle Eocene strata. In the upper Tertiary, the latest occurrences of *Cyclococcolithus macintyrei* and of abundant discoasters mark a boundary near that between the Pliocene and Pleistocene. The last occurrences of the abundant and widespread *Sphenolithus neoabies* and *Reticulofenestra pseudoumbilica* (Gartner) offer a useful boundary in the middle of the Pliocene.

## II. ACKNOWLEDGMENT

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## III. Samples by Region

*Atlantic Ocean*

Lamont core V3-153 (28°24′N., 77°56′W.).
Lamont core V12-5 (21°12′N., 45°21′W.).
Lamont core V16-21 (17°16′N., 48°25′W.).
JOIDES core 3 (21°30′N., 77°31′W.).
JOIDES core 4 (31°02′N., 77°43′W.).
JOIDES core 6 (30°05′N., 79°15′W.).
DSDP core 25 (0°31′S., 39°14′W.).

*Gulf of Mexico*

DSDP core 2 (23°27′N., 92°35′W.).
DSDP core 3 (23°01′N., 92°01′W.).

*Pacific Ocean*

Scripps core AMPH 116P (11°26′S., 149°17′W.).

*Indian Ocean*

Scripps dredge sample DODO 123D-1 (10°25′S., 63°15′E.).

*Europe*

Lower part of type Plaisancian, 200 meters south of Lugagnano in Torrente Arda, to south of Piacenza (Plaisance) in Po Valley, Italy.
Pliocene, Le Castella #81, Crotone, Calabria, southern Italy [see Emiliani, Mayeda, and Selli (1961)].

*South America*

Type locality, *Globorotalia pseudomenardii* Zone, lower part of Lizard Springs Formation, TLL 228, 674 (HGK 10832), Trinidad; sample supplied by H. M. Bolli.

*North America*

Middle Eocene, Cook Mountain Formation, Columbus Landing, Louisiana.
Middle Eocene, Formación Aragón, type locality, El Rio la Puerta, west-southwest of La Antiqua, Mexico.
Middle Eocene, Formación Guayabal, type locality, Galle-Camino de Potrero Hacienda de Tamatoco, Mexico.
Middle Eocene, Gosport Sand, Little Stave Creek, Jackson, Alabama, Bandy collecting locality 36.
Middle Eocene, Lisbon Formation, Little Stave Creek, Jackson, Alabama, Bandy collecting locality 30.
Eocene, Tillamook Volcanic Series, Tillamook County, northwest Oregon. The sample, supplied by P. D. Snavely, Jr., is an oil shale within this series.
Upper Eocene, type Yazoo Clay, 5 meters above base, east bank of Yazoo River in sec. 32, T. 12 N., R. 2 E., at Yazoo City, Mississippi. Sample from H. L. Levin.
Upper Eocene, Cocoa Sand Member of Yazoo Clay, 3.5 miles southeast of Isney on the road to Silas, Choctaw County, Alabama.

## IV. Systematic Paleontology

### Genus Cyclococcolithus Kamptner, 1954

### Cyclococcolithus macintyrei Bukry and Bramlette, n. sp.

Pl. 1, figs. 1-3

*Coccolithus leptoporus* (Murray and Blackman) var. A, McIntyre, Bé, and Preikstas, 1967, p. 9-10, pl. 4, figs. C-D.
*Cyclococcolithus leptoporus* (Murray and Blackman). Gartner, 1967, p. 1, pl. 1, figs. 1, 2, 4a-4c; pl. 2, figs. 1, 3a-3c, 4a-4d.

*Description*: These large circular coccoliths are constructed of two shields with a connecting tube. Each shield is formed by a single cycle of about 40 elements. The interelement sutures are slightly curved on the distal surface of the distal shield; otherwise the sutures are radial and straight. In cross-polarized light only the smaller proximal shield is bright.

*Remarks*: Although McIntyre, Bé, and Preikstas considered this to be one of three varieties of *Cyclococcolithus leptoporus* (Murray and Blackman), *Cyclococcolithus macintyrei* may be easily distinguished by a consistently larger number of elements (approximately 40 versus about half that number in other varieties) and by its large size (approximately 11 microns versus about 6 microns). *C. macintyrei* is therefore distinguished as a new species.

*Distribution*: Whereas *C. macintyrei* ranges only from middle Miocene to upper Pliocene, or sparsely to lowermost Pleistocene, other varieties of *C. leptoporus* range from lower Miocene to Holocene. *C. macintyrei* is abundant in samples from all oceans and from land strata. Much information on the taxonomic problems and distribution of *Cyclococcolithus leptoporus* has been presented by McIntyre, Bé, and Preikstas (1967) and by Gartner (1967).

*Size*: 8-12 microns.
*Holotype*: USNM 651407 (Pl. 1, fig. 1).
*Paratype*: USNM 651408.

*Type locality*: Lower Pliocene, type Plaisancian, Lugagnano, Italy.

Genus DISCOASTER Tan, 1927

DISCOASTER NEOHAMATUS

Bukry and Bramlette, n. sp.

Pl. 1, figs. 4-5

*Description*: This species has six long slender rays, the outer ends of which bend consistently in one direction (in plan view) and terminate in points. No distinct central area nor ornamentation is present.

*Remarks*: Where overgrown with secondary calcite, the rays appear to be more curved than otherwise. This species may have developed from five-rayed *Discoaster hamatus* Martini and Bramlette or six-rayed *Discoaster calcaris* Gartner, but both these species have tips that bend more abruptly and possess distinctive spurs not found on *Discoaster neohamatus*.

*Distribution*: The first occurrence of *D. neohamatus* is found in the lower part of the upper Miocene; the last occurrence is also within the upper Miocene. Because of this restricted range this species is useful in helping delimit the lower part of the upper Miocene. The tentative *Triquetrorhabdulus rugosus* Zone, as used by Bukry and Bramlette (in press) for these strata, is better characterized by the range of *D. neohamatus* and we propose that name change. The *Discoaster neohamatus* Zone is thus assigned to the lower part of the upper Miocene and is defined at the base by the last occurrence of *D. hamatus* and at the top by the first occurrence of *Ceratolithus tricorniculatus* Gartner. *D. neohamatus* has a wide geographic distribution and is particularly common in open-ocean deposits.

*Size*: 10-15 microns.

*Holotype*: USNM 651409 (Pl. 1, fig. 4).

*Paratype*: USNM 651410.

*Type locality*: Blake Plateau, JOIDES core 3, 21 meters.

DISCOASTER QUINTATUS

Bukry and Bramlette, n. sp.*

Pl. 1, figs. 6-8

*Discoaster brouweri* Tan, BANDY and WADE, 1967, pl. 1, figs. 3 and 4.

*Description*: This symmetric, consistently five-rayed species has a pentagonal central area that may occupy up to a third of the overall diameter. There is a star-shaped knob on the concave side, the rays of which bisect the angle between the extended rays of the discoaster. This central knob is commonly less developed in the later part of the range of the species (Pl. 1, figs. 7-8). The robust rays are straight in plan view and taper uniformly.

*Remarks*: This species is distinguished by the tapered straight rays (in plan view) and robust central area, which has a five-rayed central knob. *Discoaster brouweri* Tan lacks these features, but in late occurrences of *D. quintatus*, where the knob is less prominent, some specimens may closely resemble a five-rayed *D. brouweri*. The unusual crystallographic orientations of the rays of some specimens (orientations similar to *Micrantholithus*) and the five-rayed construction indicate that *Discoaster quintatus* is structurally similar to *D. pentaradiatus*, which shows both of these features. *D. quintatus* differs, however, in its lack of bifurcating rays, by distinctly tapered rays, and by its star-shaped central knob. Electron micrographs of "*Discoaster* sp." in the Leg-1 Report of the Deep Sea Drilling Project (Bukry and Bramlette, 1969) are referable to this new species.

*Distribution*: *D. quintatus* is a common species in lower upper Miocene into lower Pliocene strata in many regions.

*Size*: 8-16 microns.

*Holotype*: USNM 651411 (Pl. 1, fig. 7).

*Paratypes*: USNM 651412 and 651413.

*Type locality*: Lamont core V3-153, 531 cm.

Genus HELICOPONTOSPHAERA

Hay and Mohler, 1967

[*nom. subst. pro Helicosphaera* Kamptner, 1954]

HELICOPONTOSPHAERA PAPILLATA

Bukry and Bramlette, n. sp.

Pl. 2, figs. 1-2

*Description*: This large species is broadly elliptical in outline and the central area is biconvex. The surfaces of both the rim and central area possess a distinctive fine papillate ornamentation. In cross-polarized illumination the rim and central area are bright.

*Remarks*: The unique surface ornamentation, and imperforate, biconvex central

* See page 142.

area distinguish this species from all others described in this genus.

*Distribution*: This species occurs in the type Formación Aragón in Mexico, which has a very abundant assemblage of coccoliths indicating correlation with lower middle Eocene strata in other regions. Some of the species in this formation were described by Stradner and Papp (1961).

*Size*: 11-15 microns.

*Holotype*: USNM 651414 (Pl. 2, fig. 1).

*Paratype*: USNM 651415.

*Type locality*: Type Formación Aragón, La Antigua, Mexico.

### Helicopontosphaera sellii
Bukry and Bramlette, n. sp.
Pl. 2, figs. 3-7

*Description*: The central area of this small species contains a large elliptical opening bridged by a single bar that may be either parallel to the short axis of the coccolith or distinctly oblique. Phase-contrast and cross-polarized lighting show the crossbar to be in optical continuity with the surrounding coccolith structure.

*Remarks*: *Helicopontosphaera sellii* is distinguished from the usually associated *Helicopontosphaera kamptneri* Hay and Mohler by having a large elliptical central opening bridged by a bar instead of being "imperforate or with two small slits." Other species of the genus from the lower Tertiary that have crossbars are typically larger forms and in cross-polarized light show different structural patterns than *H. sellii.*

*Distribution*: *H. sellii* is common in the upper Miocene and Pliocene of many regions: Italy, Atlantic Ocean, Gulf of Mexico, and the tropical Pacific Ocean.

*Size*: 6-12 microns.

*Holotype*: USNM 651416 (Pl. 2, figs. 3-4).

*Paratype*: USNM 651417.

*Type locality*: Le Castella 81, Calabria, southern Italy.

### Leptodiscus larvalis
Bukry and Bramlette, n. gen., n. sp.
Pl. 2, figs. 8-11

*Description*: These circular coccoliths are constructed of a single cycle of 31-37 slightly inclined elements constituting a single shield. On one side the sutures are straight and on the opposite side curved. The small open central area is encircled by a collar and occupies less than 20 percent of the coccolith diameter.

*Remarks*: This species is extremely thin and is best observed in phase-contrast illumination. In cross-polarized illumination, only the central collar yields more than a faint image. *Leptodiscus larvalis* is distinguished from other concurrent circular coccoliths, *Cyclococcolithus lusitanicus* (Black) and *Cyclococcolithus neogammation* Bramlette and Wilcoxon, by the thin single-shield construction with little imbri-

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## Plate 1
Magnification 2000 ×

Figures — Page

1-3 *Cyclococcolithus macintyrei* Bukry and Bramlette, n. sp. ---- 132
(1) holotype USNM 651407, type Plaisancian; (2) V12-5, 700 cm, USNM 651408; (3) cross-polarized.

4-5 *Discoaster neohamatus* Bukry and Bramlette, n. sp. ---- 133
(4) holotype USNM 651409, J3, 21 meters; (5) DSDP-25, 20 meters, USNM 651410.

6-8 *Discoaster quintatus* Bukry and Bramlette, n. sp. ---- 133
(6) DSDP-3, 538 meters USNM 651412; (7) holotype USNM 651411, V3-153, 531 cm; (8) J3, 3 meters, USNM 651413.

9-14 *Triquetrorhabdulus inversus* Bukry and Bramlette, n. sp. ---- 142
(9) holotype USNM 651436, J3, 163 meters, parallel to polarizer; (10) perpendicular to polarizer; (11) 45° to polarizer, cross-polarized; (12) J3, 163 meters, parallel to polarizer, USNM 651437; (13) perpendicular to polarizer; (14) 45° to polarizer, cross-polarized.

PLATE 1

cation of the rim elements and by the central collar.

Most circular single-shield coccoliths have been referred to the genus *Calcidiscus* Kamptner, 1950. However, the type species and others assigned to that genus apparently are all fragments derived from species of the two-shield genus *Cyclococcolithus* Kamptner, 1954.

*Distribution*: *Leptodiscus larvalis* is known from the upper Eocene type Yazoo Clay of Mississippi, and from the lower Oligocene of JOIDES cores on the Blake Plateau, J3, 130 to 136 meters and J6, 30 to 48 meters.

*Size*: 10 to 13 microns.

*Holotype*: USNM 651418 (Pl. 2, figs. 8-9).

*Paratypes*: USNM 651419 and 651420.

*Type locality*: Blake Plateau, JOIDES core 6, 34 meters.

Genus MICRANTHOLITHUS Deflandre, 1950

MICRANTHOLITHUS PROCERUS
Bukry and Bramlette, n. sp.
Pl. 2, figs. 12-15

*Description*: In plan view, each of the five triangular segments has a slight median indentation in the rounded marginal side. In side view, the usual orientation in study slides, this large species is seen to be very tall (one to two times the greater diameter of the base). Well-preserved specimens are widest at their flat base, tapering upwards to a rounded termination, and show a multilamellar structure which is parallel to the base.

*Remarks*: The extraordinary height compared with the basal diameter causes specimens to be almost invariably oriented on their sides and results in high birefringence, which make this species readily recognizable. The marginal outline of *Micrantholithus procerus* resembles that of *Micrantholithus basquensis crassus* Bouché. *M. procerus* is easily distinguished by its very tall and slightly tapering shape in side view.

*Distribution*: *M. procerus* occurs in upper middle Eocene strata in France, Indian Ocean (DODO 123 D-1), Louisiana, Alabama, Mexico, and Brazil. It is unusually abundant in JOIDES core 3 from 155 to 163 meters, Blake Plateau.

*Size*: height, 10-20 microns.

*Holotype*: USNM 651421 (Pl. 2, fig. 13).

*Paratypes*: USNM 651422 to 651424.

*Type locality*: Type Formación Guayabal, Mexico.

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PLATE 2

Magnification 2000 ×

Figures — Page

1-2 *Helicopontosphaera papillata* Bukry and Bramlette, n. sp. ---- 133
(1) holotype USNM 651414, type Formación Aragón; (2) type Formación Aragón, cross-polarized, USNM 651415.

3-7 *Helicopontosphaera sellii* Bukry and Bramlette, n. sp. ---- 134
(3) holotype USNM 651416, Le Castella 81; (4) cross-polarized; (5) V16-21, 200 cm, USNM 651417; (6) cross-polarized; (7) V16-21, 150 cm, figured specimen, cross-polarized.

8-11 *Leptodiscus larvalis* Bukry and Bramlette, n. gen., n. sp. ---- 134
(8) holotype USNM 651418, J6, 34 meters; (9) phase-contrast; (10) J6, 34 meters, phase-contrast, USNM 651419 and 651420; (11) cross-polarized.

12-15 *Micrantholithus procerus* Bukry and Bramlette, n. sp. ---- 136
(12) holotype USNM 651421, type Formación Guayabal, side view; (13) type Formación Guayabal, cross-polarized, USNM 651422; (14) Cook Mountain Formation, USNM 651423; (15) J3, 155 meters, end view, USNM 651424.

16-19 *Pemma snavelyi* Bukry and Bramlette, n. sp. ---- 138
(16) holotype USNM 651425, Lisbon Formation; (17) cross-polarized; (18) Tillamook Volcanic Series, single segment, cross-polarized, USNM 651426; (19) Gosport Sand, cross-polarized, USNM 651427.

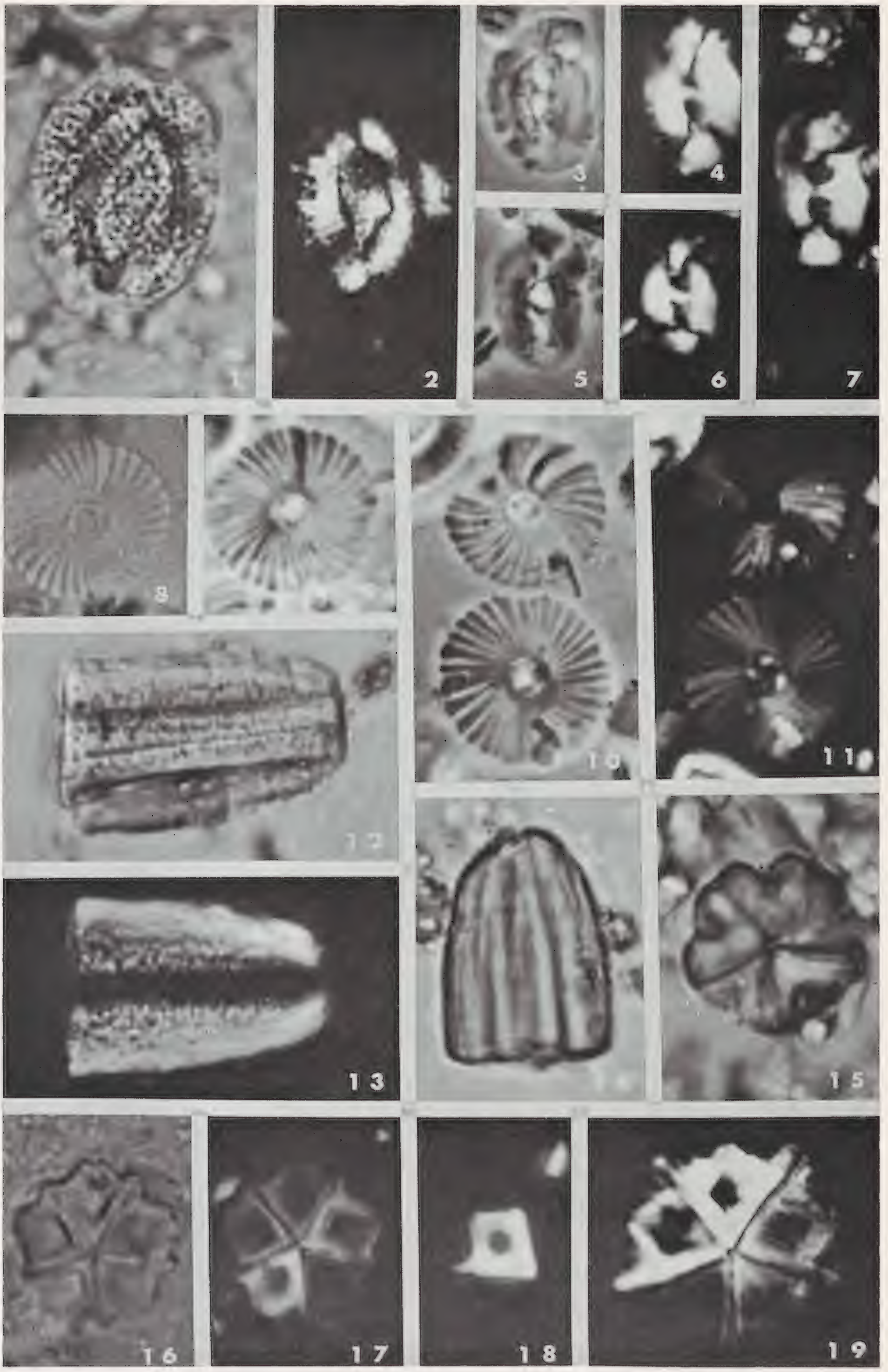


PLATE 2

Genus PEMMA Klumpp, 1953

PEMMA SNAVELYI
Bukry and Bramlette, n. sp.

Pl. 2, figs. 16-19

*Description*: These pentaliths are characterized by slender extensions along the radial sutures of each segment that extend beyond the pentagonal periphery, and by a distinctive broad, angular, median protrusion from the margin of the five segments. A rounded or diamond-shaped depression is present at the center of each segment.

*Remarks*: The only species similar to *Pemma snavelyi* is *Micrantholithus basquensis* Martini, 1959. *P. snavelyi* is distinguished by the relative lengths of the marginal protrusions. The overall outline of *M. basquensis* is circular, all depressions or protrusions being the same size, with four equal marginal protrusions per segment, whereas the overall outline of *P. snavelyi* is a pentagon having long protrusions at the segment sutures, with three protrusions per segment.

*Distribution*: *P. snavelyi* occurs in the upper middle Eocene Cook Mountain Formation of Louisiana, in the approximately equivalent Lisbon Formation of Alabama, and in an oil shale within the Eocene Tillamook Volcanic Series of Oregon.

*Size*: 10 to 17 microns.

*Holotype*: USNM 651425 (Pl. 2, figs. 16-17).

*Paratypes*: USNM 651426 and 651427.

*Type locality*: Lisbon Formation, Little Stave Creek, Alabama.

QUINQUERHABDUS COLOSSICUS
Bukry and Bramlette, n. gen., n. sp.

Pl. 3, figs. 1-4

*Description*: In plan view the base of this peculiar species is seen to be oval shaped and composed of five segments (oriented as in *Micrantholithus*). Owing to the large size and high tapering shape of the segments, the species is rarely seen in any orientation but a side view, where it shows an approximately triangular outline. In side view two of the five segments are seen meeting along the apical axis of the coccolith. The base of the segments is thick, however, and the structure thins upwards into vanes that terminate in a point.

*Remarks*: This unusual form seems related to *Braarudosphaera* and *Micrantholithus* by its pentameral symmetry of the base (vaguely shown in Pl. 3, fig. 3). Very different from these genera, however, is the abrupt concave taper from the base. Although the thickened portion of segments always shows this concave taper, some with flaring thin vanes may show a convex out-

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PLATE 3

Magnification 2000 ×

Figures — Page

1-4 *Quinquerhabdus colossicus* Bukry and Bramlette, n. gen., n. sp. ..... 138
(1) holotype USNM 651428, side view, J6, 34 meters; (2) cross-polarized; (3) J3, 136 meters, end view, figured specimen; (4) J3, 136 meters, single segment, figured specimen.

5-8 *Sphenolithus anarrhopus* Bukry and Bramlette, n. sp. ..... 140
(5) holotype USNM 651429, side view, cross-polarized, 0°, J4, 150-153 meters; (6) 10-20°; (7) 45°; (8) phase-contrast, 90°.

9-11 *Sphenolithus neoabies* Bukry and Bramlette, n. sp. ..... 140
(9) holotype USNM 651430, cross-polarized, 0°, V16-21, 475 cm; (10) phase-contrast, 45°; (11) cross-polarized, 45°.

12-14 *Syracosphaera formosa* Bukry and Bramlette, n. sp. ..... 140
(12) type Formación Aragón, side view, USNM 651431; (13) holotype USNM 651432, type Formación Aragón; (14) cross-polarized.

15-17 *Syracosphaera labrosa* Bukry and Bramlette, n. sp. ..... 141
(15) Yazoo Clay, Cocoa Sand Member, side view, USNM 651434; (16) holotype USNM 651433, Cook Mountain Formation; (17) cross-polarized.

18 *Thoracosphaera prolata* Bukry and Bramlette, n. sp. ..... 141
(18) holotype USNM 651435, AMPH 116P, 488 cm.

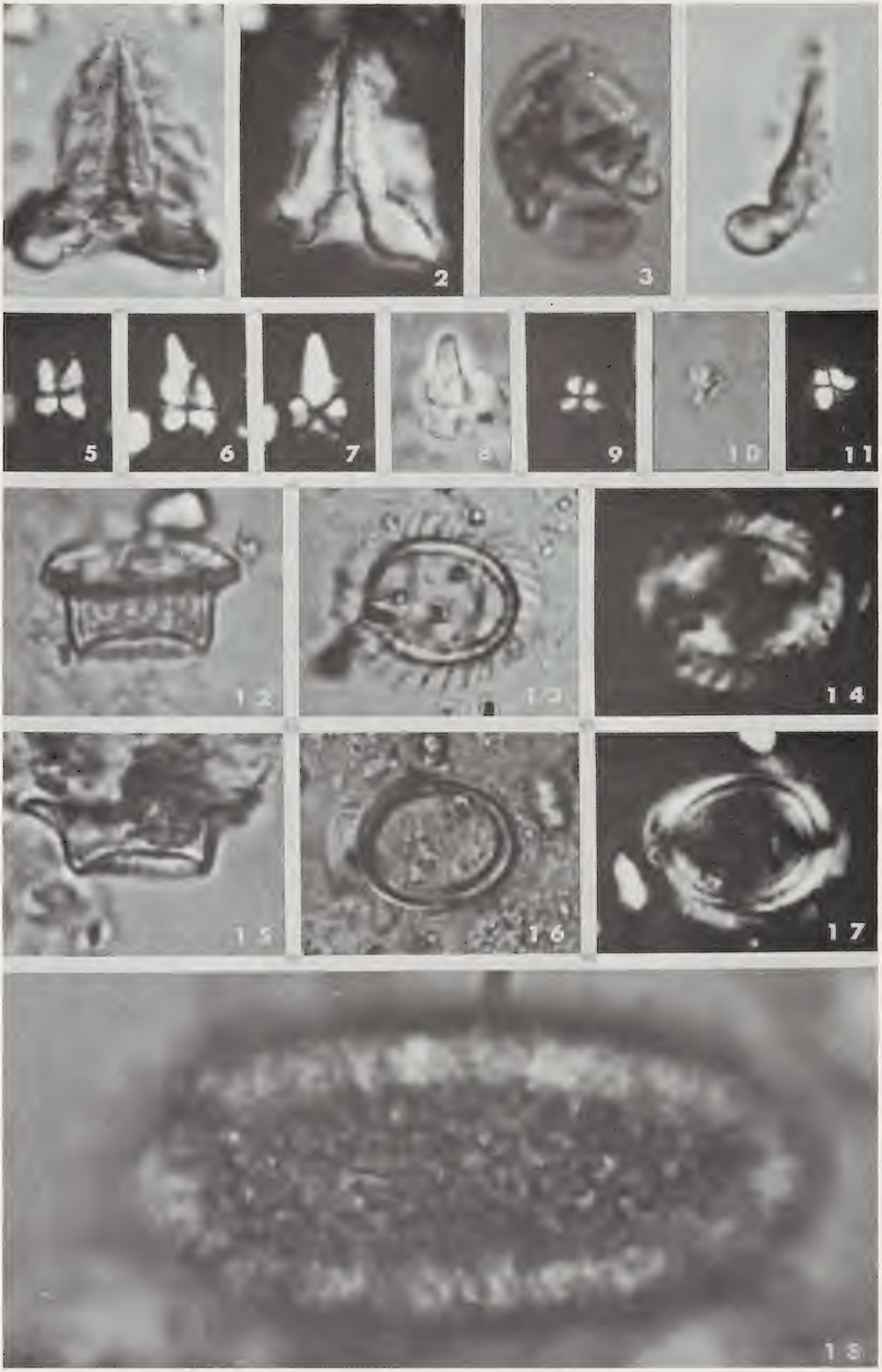


PLATE 3

line of this thin edge. The five segments are easily separated and usually are abundant in samples containing *Q. colossicus.*

*Distribution*: *Q. colossicus* is presently known only from the lower Oligocene of the Blake Plateau, east of Florida, from JOIDES core 3, 118 to 144 meters, and core 6, 19 to 43 meters.

*Size*: height, 10-18 microns.

*Holotype*: USNM 651428 (Pl. 3, figs. 1-2).

*Type locality*: Blake Plateau, JOIDES core 6, 34 meters.

Genus SPHENOLITHUS Deflandre, 1952

SPHENOLITHUS ANARRHOPUS

Bukry and Bramlette, n. sp.

Pl. 3. figs. 5-8

*Description*: This small species shows a relatively compact (nonflaring) group of basal spines and an unusual apical spine. As in other species of *Sphenolithus*, the specific structural features are best observed in cross-polarized light. In side view when the axis of the apical spine is aligned to either of the polarizing directions, only the basal structure can be seen, whereas when rotated to a position of 45°, the spine is bright and appears to be a monolithic structure. The apical spine is asymmetric in this position; however, the asymmetry is more distinct in the 10° to 20° position where the spine appears to be tilted (Pl. 3, fig. 6).

*Remarks*: The asymmetry of the spine distinguishes *Sphenolithus anarrhopus* from the similar *Sphenolithus heteromorphus* Deflandre, which has a symmetric apical spine. In cross-polarized illumination, populations of these two species are further distinguished by the four nearly equal-area divisions of the base in *S. anarrhopus* (Pl. 3, fig. 5) and the unequal division (lower two usually larger) in *S. heteromorphus. Sphenolithus radians* Deflandre has a symmetric spine with distinct median separation apparent under crossed polarizers.

*Distribution*: *S. anarrhopus* is present in Thanetian equivalents of the Paleocene in widely scattered areas such as California, central Atlantic Ocean, Blake Plateau JOIDES core 4, 137 to 178 meters, and the *Globorotalia pseudomenardii* Zone of Trinidad.

*Size*: height, 5-8 microns.

*Holotype*: USNM 651429 (Pl. 3, figs. 5-8).

*Type locality*: Blake Plateau, JOIDES core 4, 150 to 153 meters.

SPHENOLITHUS NEOABIES

Bukry and Bramlette, n. sp.

Pl. 3, figs. 9-11

*Sphenolithus*? sp. MARTINI and BRAMLETTE, 1963, p. 855, pl. 102, figs. 6-7.

*Description*: This small species lacks the prominent apical spine typical of most species of the genus; however it does possess the radial array of tiny spines typical of the basal structure of *Sphenolithus.* Owing to its small size, this species is clearly visible only in cross-polarized illumination.

*Remarks*: *Sphenolithus neoabies* is distinguished by its lack of a prominent apical spine and by its very small size (2 to 4 microns). The only other species without a prominent apical spine, *S. moriformis* (Brönnimann and Stradner), appears to be similar in cross-polarized illumination, but is much larger. *S. neoabies* is distinguished from equally small circular coccoliths, as seen under crossed polarizers, by having a digitate, instead of a smooth, margin. It is similar to the closely related *S. abies*, but is smaller and less conical because the apical spines are less extended.

*Distribution*: *S. neoabies* is commonly associated with *S. abies* in the upper Tertiary of many regions, but either dominates or becomes the only species of *Sphenolithus* in the latest occurrences near the middle of the Pliocene.

*Size*: 2 to 4 microns.

*Holotype*: USNM 651430 (Pl. 3, figs. 9-11).

*Type locality*: Lamont core V16-21, 475 cm.

Genus SYRACOSPHAERA Lohmann, 1902

SYRACOSPHAERA FORMOSA

Bukry and Bramlette, n. sp.

Pl. 3, figs. 12-14

*Description*: This high-walled species has a distinctively curving cycle of 26-32 elements in the flaring flange portion of the wall structure. The central structure is evidently very thin and gives no distinctive pattern in light microscopy.

*Remarks*: *Syracosphaera formosa* is simi-

lar to *Syracosphaera labrosa* Bukry and Bramlette, n. sp., but *S. labrosa* shows only a faint rim in which individual elements are not evident in either normal bright-field or cross-polarized light microscopy. *S. formosa* is distinguished from *Syracosphaera fimbriata* (Bramlette and Sullivan) by its lack of two distinctive central-area perforations.

*Distribution*: *S. formosa* occurs in the middle Eocene Formación Aragón of Mexico.

*Size*: 13-17 microns.

*Holotype*: USNM 651431 (Pl. 3, figs. 13-14).

*Paratype*: USNM 651432.

*Type locality*: Type Formación Aragón, Mexico.

### Syracosphaera labrosa
Bukry and Bramlette, n. sp.

Pl. 3, figs. 15-17

*Reticulofenestra caucasica* Hay, Mohler, and Wade, 1966 (*partim*), p. 386, pl. 2, figs. 6-8, not fig. 5, not pl. 3 nor pl. 4. Levin and Joerger, 1967, p. 168, pl. 2, fig. 2a-b.

*Description*: This large high-walled, elliptical species has a flanged extension of the wall on the distal side. The flange is composed of a large number of narrow elements and thus appears smooth and translucent; only the side walls are conspicuous in normal transmitted light. In cross-polarized illumination, the optical extinction lines pass beyond the wall into the large central area, which indicates the presence of a thin basal structure.

*Remarks*: The taxonomy of *Syracosphaera labrosa* is confused. The type species of *Reticulofenestra* was *Reticulofenestra caucasica* Hay, Mohler, and Wade, 1966. However, our electron-microscope examination of topotype material of *Coccolithus umbilicus* Levin, 1965, has shown that the electron-micrograph holotype of *R. caucasica* = *C. umbilicus*. *C. umbilicus* is constructed of two distinct shields (a placolith) which produce a broad bright oval ring when observed in cross-polarized light. The light micrographs presented by Hay, Mohler, and Wade as paratypes, however, show a syracosphaerid single-rim type of wall. The electron micrographs of *Reticulofenestra oamaruensis* (Deflandre) Stradner and Edwards and the original light micrographs of Deflandre show that that species has a substantial central area structure with a distinctive median suture and a syracosphaerid-type rim without a flange (therefore, possibly referable to *Discolithina*). These features are quite different from those of *S. labrosa.*

*Syracosphaera formosa* Bukry and Bramlette, n. sp., and *Syracosphaera fimbriata* (Bramlette and Sullivan) are distinguished from *S. labrosa* by structural details that are obvious in light microscopy. *S. labrosa* has a translucent flange and a featureless central area; in contrast, *S. formosa* shows a definitely inclined cycle of 26 to 32 elements in the flange, and *S. fimbriata* has two large perforations in its base.

*Distribution*: Though not abundant, *S. labrosa* is present in the upper middle Eocene to lower Oligocene of many areas.

*Size*: 14-18 microns.

*Holotype*: USNM 651433 (Pl. 3, figs. 16-17).

*Paratype*: USNM 651434.

*Type locality*: Cook Mountain Formation, Columbus Landing, Louisiana.

## Genus Thoracosphaera Kamptner, 1927

### Thoracosphaera prolata
Bukry and Bramlette, n. sp.

Pl. 3, fig. 18

*Description*: This is an unusually large thick-walled species with a shell in the shape of a very prolate spheroid. The shell is composed of a mosaic of irregular, thick interlocking elements. The surface is not "smooth," as the sutures are slightly depressed. Characteristically the eccentricity (long axis/short axis) of the shell is 2.0 or greater.

*Remarks*: No other species of *Thoracosphaera* has such a strongly prolate spheroidal shape as *Thoracosphaera prolata.* The distinctly "sculptured" appearance of the surface is also characteristic. There are ovoid (much less prolate) forms associated with *T. prolata*; these forms also occur in younger strata.

*Distribution*: *T. prolata* occurs in the middle Eocene of the three major oceans and in Lutetian equivalents in southwest France, Trinidad, USSR, and elsewhere.

*Size*: 25-50 microns.

*Holotype*: USNM 651435 (Pl. 3, fig. 18).

*Type locality*: Scripps core AMPH 116P, 488 cm, Pacific Ocean.

Genus TRIQUETRORHABDULUS Martini, 1965

TRIQUETRORHABDULUS INVERSUS
Bukry and Bramlette, n. sp.
Pl. 1, figs. 9-14

*Description*: The uniform crystallographic orientation of the keels of this three-edged rod is such that parallel to the polarizing direction the two side keels show distinct outlines (strong relief in 1.55 index medium), whereas perpendicular to the polarizing direction only the high upper keel is distinct, and the lower keels are faint owing to their thinness in this orientation. These effects are seen with one polarizer in the optic system. The position of maximum birefringence, as indicated by bright appearance in cross-polarized light, is at 45°. Although both ends of the rod taper, one end is usually more acute than the other. Secondary overgrowth of calcite commonly causes a ragged appearance on the keels.

*Remarks*: *Triquetrorhabdulus inversus* is distinguished from *Triquetrorhabdulus carinatus* Martini by having the opposite crystallographic orientation of the keels or long axis. With a single polarizer, *T. inversus* conversely gives a distinct outline in the direction for which *T. carinatus* shows a faint outline.

Further study has indicated that a suggested emendation, concerning the crystallographic orientation, of this genus (Bramlette and Wilcoxon, 1967) should be disregarded.

*Distribution*: *T. inversus* is common throughout the middle Eocene of all three major oceans, in Lutetian equivalents of southwest France, Trinidad, California, and many other areas.

*Size*: 12-22 microns.

*Holotype*: USNM 651436 (Pl. 1, figs. 9-11).

*Paratype*: USNM 651437.

*Type locality*: Blake Plateau, JOIDES core 3, 163 meters.

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* DISCOASTER QUINTATUS [see page 133]: *Discoaster quinqueramus* Gartner, 1969, Gulf Coast Assoc. Geol. Soc., Trans., v. 19, p. 598, pl. 1, figs. 6-7, was published while this paper was in press and has priority.

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# CENOZOIC TYPHINAE (MOLLUSCA:GASTROPODA) OF THE WESTERN ATLANTIC REGION

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## I. ABSTRACT

Twenty-six genus-group names have been proposed for the muricid subfamily Typhinae. This study shows that four genera and 17 subgenera are valid, with approximately 125 fossil and Recent species. Of these, three genera, nine subgenera, and 36 species are known from the Cenozoic of the western Atlantic region, including three species from the Eocene, two from the Oligocene, 22 from the Miocene, one from the Pliocene, and four from the Pleistocene and Recent. In addition, four species are known only from the Recent fauna.

In this paper, all of the species are treated systematically, including ten new species: *Typhis (Typhina) palmerae,* from the early middle Eocene Weches and Wautubbee formations of Texas and Mississippi, respectively; *T. (Typhina) mississippiensis,* from

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the lower Oligocene Red Bluff Clay of Mississippi; *T.* (*Rugotyphis*) *keenae*, *T.* (*Typhinellus*) *chipolanus, Pterotyphis* (*Pterotyphis*) *calhounensis*, and *P.* (*Tripterotyphis*) *vokesae*, all from the late lower Miocene Chipola Formation of northwestern Florida; *Typhis* (*Talityphis*) *carmenae,* from the upper Miocene Agueguexquite Formation of Mexico; *Siphonochelus* (*Pilsbrytyphis*) *darienensis* and *S.* (*P.*) *woodringi,* both from the middle Miocene of Panamá; and *Siphonochelus* (*Laevityphis*) *bullisi,* from the Pleistocene Móin Formation of Costa Rica and the Recent Caribbean.

The oldest known typhine in the world is referred to *Siphonochelus* (*Laevityphis*), reported from the lower Eocene of England and France. This earliest form is a well developed typhine, from which it is concluded that the group must have evolved at an earlier time. Among the first Typhinae in the western Atlantic is also a representative of *Siphonochelus* (*Laevityphis*), occurring in the late middle Eocene of Alabama. The oldest reported typhine in the western Atlantic region is *T.* (*Typhina*) *palmerae,* n. sp., from the early middle Eocene of Mississippi and Texas.

Typhinae have shells of less than 50 mm length with a protoconch of one and one-half to five whorls. Tubes are present at the shoulder, either alternating with, or within the varices. The number of varices may vary from two to six, but most forms have four varices and four tubes per whorl. The aperture is ovate and surrounded by a raised rim. The anterior canal is closed in all but one group. Generic and subgeneric units are based primarily upon the nature of the varices, the number of varices per whorl, the placement of the tubes with respect to the varices (just behind the varix, just in front of the varix, midway between the varices, or within the varix), and the direction in which the tubes point.

A summary of the reported ecological data shows that the Typhinae live, for the most part, in shallow water in tropical and subtropical areas.

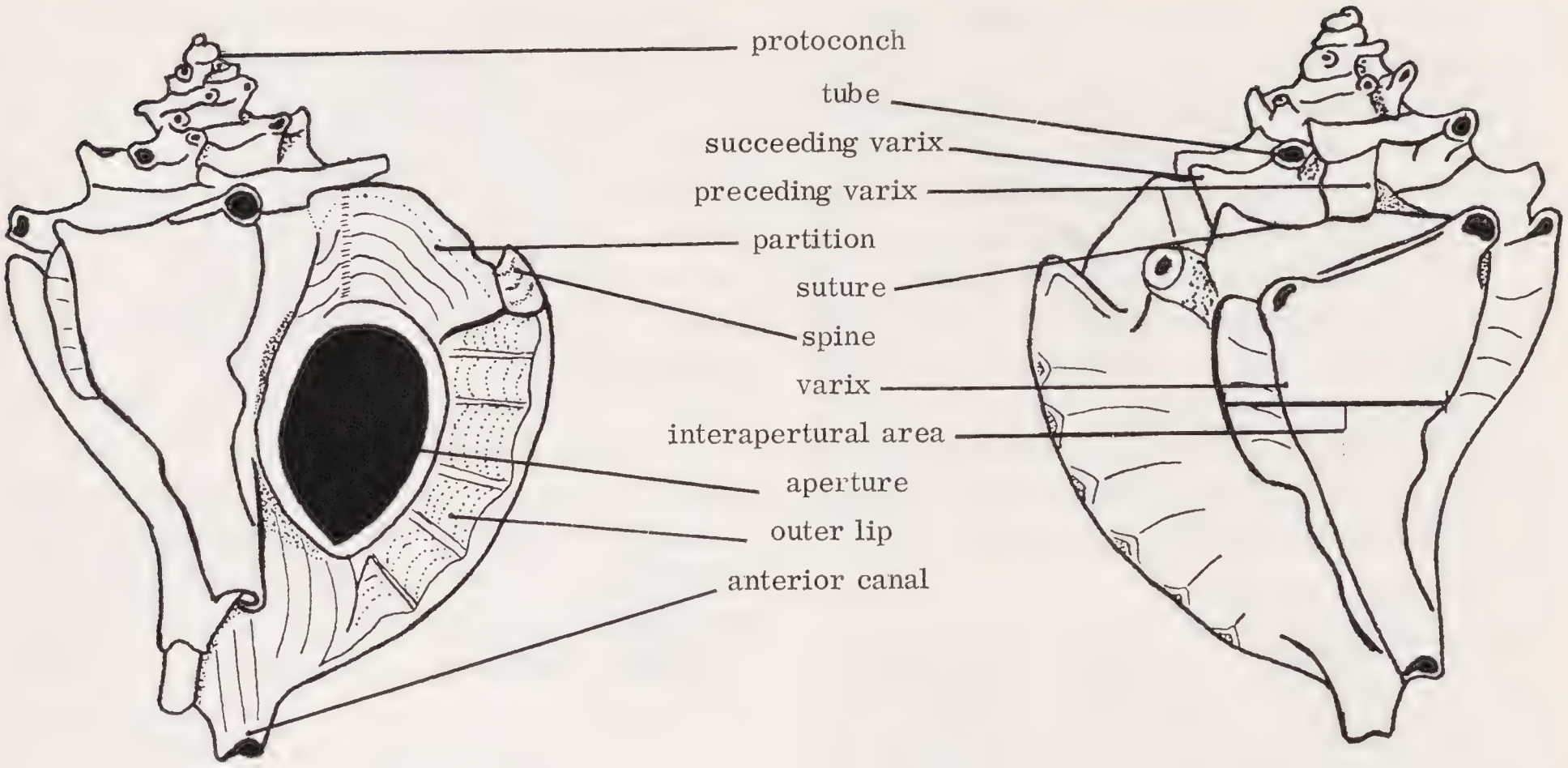
## II. Introduction

The genus *Typhis,* established in 1810 by Denys de Montfort, includes those gastropods having a shell of small size, with two to six varices and tubes per whorl, the tubes within or between the varices; the aperture surrounded by a raised rim; anterior canal closed in all but one group; protoconch of one and one-half to five whorls. The type, by original designation, is *"Purpura" tubifer* Bruguière, 1792, from the middle Eocene of the Paris Basin.

Jousseaume (1880, 1882) first divided the typhines into twelve genera. Cossmann (1903) established the subfamily Typhinae, recognizing four genera with eight subgenera. Keen (1944) accepted four genera with 13 subgenera. Vella (1961) included nine genera in the subfamily. In 1964, Keen and Campbell described an unusual new genus, *Distichotyphis* from very deep water (1016 fms.) with only two varices and tubes per whorl. In all, there have been 26 supraspecific names proposed for the Typhinae. Of these the writer recognizes as valid four genera with 17 subgenera.

The problem of genus-groups is especially complex in the Typhinae. At first glance it would appear that there is an overabundance of taxa recognized for a relatively few species. At the present writing there are approximately 125 known species of Typhinae, both fossil and Recent. Of these, Vella described eight from New Zealand in 1961, Keen and Campbell added ten new species in 1964, and the present work adds ten new species from the western Atlantic region. Various other authors have described six more species for a total of 34 new species in the last eight years. This represents about one-quarter of the total number of species and, undoubtedly, many more will be discovered in time to come. It seems obvious that the Typhinae, on the whole, are poorly known and with future work many of the apparent discontinuities in range, both geographic and stratigraphic, will be removed. Seven of Jousseaume's 12 genera were monotypic at the time they were proposed; only one, *Haustellotyphis,* remains so today. Two other monotypic fossil subgenera, *Indotyphis* Keen, 1944, and *Semityphis* Martin, 1931, come from Java, an area where little geologic work has been done. Another monotypic genus is *Distichotyphis,* a very deep water form.

The oldest known species of Typhinae, from the lower Eocene of England and France, is referred to *Siphonochelus* (*Laevi-*




Text figure 1. Terminology applied to typhine shell.

*typhis*). As *Laevityphis* is a well developed typhine, the subfamily must have evolved at an earlier time, Paleocene or perhaps Cretaceous. As yet, however, none have been recovered from older strata. Among the earliest Typhinae in North America are *S.* (*Laevityphis*) *gracilis* (Conrad, 1833), from the late middle Eocene of Alabama and *S.* (*Laevityphis*) *antiquus* (Gabb, 1864), from the middle or upper Eocene of California. There are species of *S.* (*Laevityphis*) in the upper Eocene of Australia and Peru indicating widespread distribution by early Tertiary time. The subgenera *Typhis* s.s., *Typhina*, *Rugotyphis*, and *Indotyphis* all appear and are widely distributed during the Eocene epoch further substantiating an earlier development. The oldest reported species of Typhinae in the western Atlantic region is a member of the subgenus *Typhina.*

The morphology of the typhine shell (see text figure 1) has been well summarized by Keen (1944, p. 51) in her basic work on the Typhinae. In her classification the tubes bearing the anal siphon are of primary importance in separation of the supraspecific groups; *i.e.,* number of tubes per whorl, placement of tubes with respect to the varices (whether mid-way, or nearer the preceding or succeeding varix, or within the varix), and the direction in which the tubes point (whether toward the aperture, outward, or away from the aperture).

Vella (1961) regarded the type of varix as the most important feature in the classification of the Typhinae, using it to separate groups of related genera. The number of varices per whorl was considered to be of secondary importance, but was used to separate genera within the varix type grouping. Other characteristics, including the number of whorls in the protoconch, placement of the intervarical tubes, shape of the aperture, and orientation of the anterior canal were utilized in distinguishing subgeneric units.

The following is a list of the genera and subgenera as recognized by the writer, the number of species in each subgenus, and any ecologic data that may have been reported. The subgenera that occur in the western Atlantic region (fossil or Recent) are marked with an asterisk. Species indicated as "duplicated" are known both from fossil and Recent.

Genus: *Typhis*

*Typhis* s.s.—3 Recent species: two off Australia, 15-38 fms., sand; one off Japan, 100-150 fms. 18 fossil species.

**Typhina*—8 Recent species: three off Japan, 50-100 fms.; one off West Africa; two off Australia, 100 fms.; one off New Zealand, 60 fms.; one off West America, 0-45 fms. 8 fossil species.

*Haustellotyphis*—1 Recent species, tropical West America, 0-7 fms.

**Rugotyphis*—2 Recent species: one off Brazil and West Africa; one from

Caribbean, 33-50 fms., sand-mud. 6 fossil species.

**Typhinellus*—1 Recent species: Mediterranean and Caribbean, 27-60 fms. 4 fossil species (one duplicated).

**Talityphis*—2 Recent species: one off Baja California, 21 fms., sand; one from Caribbean, 17-30 fms., shell-mud-coral. 11 fossil species (one duplicated).

*Typhisopsis*—4 Recent species: one off Australia, 17 fms., three off tropical West America, 0-14 fms.

Genus: *Siphonochelus*

**Siphonochelus* s.s.—11 Recent species: one off Kenya, 232 fms.; one off South Africa, 40-54 fms.; one off Cuba, 127-400 fms.; eight from Australasia, 21-130 fms. 8 fossil species.

*Lyrotyphis*—2 fossil species.

*Indotyphis*—1 fossil species.

*Semityphis*—1 fossil species.

**Laevityphis*—3 Recent species: one from Indo-Pacific, 18 fms., coral-gravel; one off Zanzibar, 232 fms.; one from Caribbean, 43 fms. 13 fossil species.

**Pilsbrytyphis*—3 fossil species.

Genus *Pterotyphis*

**Pterotyphis* s.s.—2 Recent species: one from the Gulf of California; one from the Caribbean, 0-28 fms. 2 fossil species (one duplicated).

**Tripterotyphis*—6 Recent species: one from Caribbean, 17 fms.; three off tropical West America; two from Australasia. 4 fossil species (two duplicated).

*Cinclidotyphis*—1 Recent species, tropical West America.

Genus *Distichotyphis*

*Distichotyphis* s.s.—1 Recent species, off tropical West America, 1016 fms.

Five species, representative of four subgenera of Typhinae, have been reported from the intertidal zone. Most of the reported specimens of the subfamily, however, were dredged from between five and 100 fathoms, with the median depth near 30 fathoms. The deepest reported is *Distichotyphis vemae* Keen and Campbell, 1964, from 1016 fathoms (uncorrected) off the west coast of Panamá.

The literature records Typhinae from a wide range of bottom types including: mud flat, sandy-mud, sand, gravel and coral, and coral reef. *Typhis* (*Typhisopsis*) *grandis* A. Adams, 1855, was reported on a sand bottom, at 14 fathoms, from the Gulf of California with a bottom temperature of 65° F. Dall (1889, p. 216) reported *Siphonochelus longicornis* from 127-400 fathoms, with a bottom temperature between 50° and 55° F, on a mud bottom. Caramagna (1869, p. 168-170) reported *Typhis* (*Typhinellus*) *sowerbii* Broderip, 1833, gregarious on seaweed in the Gulf of Spezia, and stated it changes its locality with the seasons, moving to deeper water in cold weather.

## III. Acknowledgments

The writer wishes to thank all of the many persons who have helped to make this paper possible. Most of the material studied came from the collections of Tulane University, collected by Dr. and Mrs. Harold E. Vokes with the financial assistance of National Science Foundation Grant Number G.B. 6048. Photography of specimens was also done by Dr. and Mrs. Vokes. Recent specimens studied were collected in large measure by the U.S. Fish and Wildlife Service, Bureau of Commercial Fisheries, Pascagoula, Mississippi, and loaned through the courtesy of Harvey R. Bullis, Jr., Base Director. For the loan of type specimens, he would like to thank the authorities at the United States National Museum, the Paleontological Research Institution, the Academy of Natural Sciences of Philadelphia, Stanford University, University of California, Berkeley, University of Texas, Universidad de Mexico (UNAM), and Cornell University. For photographs of foreign type specimens he is indebted to C. P. Nuttall, British Museum (Nat. Hist.), and H. Chevallier, Muséum d'Histoire Naturelle, Paris. He would especially like to thank Dr. A. Myra Keen who laid so much of the groundwork for the study of the Typhinae, and Dr. Emily H. (Mrs. H. E.) Vokes for her continued assistance and moral support. Finally, he would like to thank the members of the editorial committee for their many useful suggestions toward the improvement of the paper.

## IV. Systematic Descriptions

### Phylum Mollusca
### Class Gastropoda
### Subclass Prosobranchia
### Order Neogastropoda
### Suborder Stenoglossa
### Family Muricidae
### Subfamily Typhinae

### Genus Typhis Montfort, 1810
### Subgenus Typhis s.s.

*Purpura* Bruguière, 1789, Encycl. Méth. (Vers), v. 1, p. xv (genus without species); Bruguière, 1792, Jour. Hist. Nat., Paris, v. 1, p. 28.
Type species: *Purpura tubifer* Bruguière, 1792, by monotypy.

*Typhis* Montfort, 1810, Conchyl. Syst., v. 2, p. 614-615.
Type species: *Typhis tubifer* (Bruguière), by original designation.

*Hirtotyphis* Jousseaume, 1880, Le Naturaliste, Année 2, no. 42, p. 336.
Type species: *Typhis horridus* (Brocchi, 1814), by original designation.

*Monstrotyphis* Habe, 1961, Coloured Illus. Shells of Japan, v. 2, p. 53; App., p. 19.
Type species: *Typhis* (*Monstrotyphis*) *tosaensis* Azuma, 1960, by original designation.

> "Coquille libre, univalve, à spire élevée, varicée et armée; bouche arrondie; columelle lisse; lèvre extérieure tranchante et armée; canal de la base large et soudé; un tube dorsal au milieu de chacun des accroissemens." (Montfort, 1810, p. 615)

Shell with four varices per whorl; tubes abapertural of midpoint between the varices, pointing abaxially and apically; varices armed with small spines; no partition present.

*Discussion*: The type of the genus *Typhis* was designated by Montfort as "*Typhis tubifer* Bruguière." He placed in his synonymy of this species "*Murex*" *pungens* Solander *in* Brander, as had Bruguière before him. The shell figured by Montfort is neither *Typhis tubifer*, which has four varical spines, nor *T. pungens*, which has three spines. Montfort's illustration shows a shell with seven or eight spines and is probably the species subsequently named *Typhis rutoti* Cossmann, 1882.

Brander (1766) figured two specimens as "*Murex*" *pungens*: pl. 3, fig. 81, the form now accepted as *Typhis pungens*; and fig. 82, which is the same as Bruguière's figured specimen (1792, pl. 2, figs. 3,4). Therefore, we may consider Bruguière as having restricted "*Murex*" *pungens* to the species figured in fig. 81 while renaming the form in fig. 82 as "*Purpura*" *tubifer*. Later, d'Orbigny (1850, p. 364) proposed another name, *Typhis parisiensis*, for "*Murex fistulosus* Brocchi" of Deshayes, 1835, pl. 80, figs. 1-3, and Brander, 1766, pl. 3, fig. 82. The first reference is for yet another species, to which the name *T. parisiensis* may be restricted, deleting the reference to the Brander figure. By way of summary, there are four species of *Typhis* s.s. in the middle Eocene beds of France and England. They are:

*T. pungens* (Solander *in* Brander, 1766): Brander, 1766, pl. 3, fig. 81.
*T. tubifer* (Bruguière, 1792): Brander, 1766, pl. 3, fig. 82; Bruguière, 1792, pl. 2, figs. 3, 4; Deshayes, 1835, pl. 82, figs. 26, 27.
*T. parisiensis* d'Orbigny, 1850: Deshayes, 1835, pl. 80, figs. 1-3.
*T. rutoti* Cossmann, 1882: Montfort, 1810, p. 614 (text fig.); Deshayes, 1835, pl. 80, figs. 4-6.

Unfortunately, by naming this typine species as "*Purpura*" *tubifer*, Bruguière inadvertently fixed the type of his genus *Purpura* (as listed in the *Tableau Systematique de Vers*, 1789) by monotypy. Although the generic name *Purpura* has had a checkered history it has never been applied to the typhine group and to replace the long accepted generic name *Typhis* with that of *Purpura* would defeat the purpose of stability sought by taxonomists. Therefore, Keen (1964) has requested that the International Commission on Zoological Nomenclature suppress this type designation and declare *Buccinum persicum* Linné as the type of *Purpura*.

Because of the errors of identification of *Typhis pungens* and *Typhis tubifer* many authors have placed the two species in synonymy, but Keen (1944, p. 53) corrected this error. *Typhis pungens* is almost inseparable from *Typhis horridus* (Brocchi, 1814), the type of *Hirtotyphis* Jousseaume, 1880. There is an unbroken line from *T. pungens* in the middle Eocene to *T. horridus* in the Pliocene. There have been two species named for the intermediate members of the line: *T. peyreirensis* Cossmann and Peyrot, 1923 (Aquitanian), and *T. intermedius* Bellardi, 1872 (Burdigalian), but

the differences between them are minimal. Another subgeneric name has been proposed for a Recent species of this group, *T.* (*Monstrotyphis*) Habe, 1961, (type: *T.* (*Monstrotyphis*) *tosaensis* Azuma) but the type species is no more than an especially spinose *Typhis* s.s. and may even be a pathologic shell as it has this appearance and is the only known specimen.

*Typhis* s.s. is found in the Eocene to Pliocene of western Europe, and in the Oligocene to Recent of the Australasian region. No *Typhis* s.s. are known from the New World.

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Subgenus TYPHINA Jousseaume, 1880

*Typhina* JOUSSEAUME, 1880, Le Naturaliste, Année 2, no. 42, p. 335; 1882, Rev. Mag. Zool., (Ser. 3) v. 7, p. 337.
Type species: *Typhis belcheri* Broderip, 1833, by original designation.

> "Coquille fusiforme à spire élevée, tours à varices crénelées, armées en arrière d'une épine saillante et recourbée, et d'un canal tubiforme intermédiaire; ouverture ovale à bords continus; canal long et recourbé." (Jousseaume, 1882)

Shell with four varices and tubes per whorl; tubes midway between varices, pointing abaxially, apically, and abaperturally; spine at shoulder; varices smooth, with flange on posterior portion only; small partition; spiral sculpture often present.

*Discussion*: The type of *T. belcheri* is not at the British Museum and there is some question as to the identity of the species. Sowerby figures, in the *Conchological Illustrations* (1841, pl. 200, figs. 5, 6), a shell with a small partition and a thin varical flange. It is possible that this specimen is really the juvenile of *T. cleryi* (Petit), which would make *Rugotyphis* a synonym of *Typhina*. However, there is a valid morphological group for which the name *Typhina* has been employed and little would be gained by replacing the name *Typhina* with another new generic name. Until such a time as positive proof of the identity of *T. belcheri* might be discovered the writer will continue to use the established name.

*Typhina* ranges from the middle Eocene to the Recent, and is represented by 16 species from the Eocene of Java and Texas, the Eocene and Oligocene of Mississippi, the Miocene of Florida, Borneo, and Australia, the Pliocene of India, and the Recent from tropical West America, Australasia, and West Africa.

This study includes three species of *Typhina* ranging from the middle Eocene through the early lower Miocene. The group is never common in the geologic record, and is most widespread and abundant in the Recent.

TYPHIS (TYPHINA) PALMERAE
Gertman, n. sp.
Plate 1, figs. 1a, b

*Description*: Shell small; protoconch of four and one-half smooth, polished, conical whorls; five post-nuclear whorls; four varices per whorl, varices formed of two parts: a thickened band surrounding the aperture, and a thin flange on the outer edge; flange very weakly crenulated by three faint folds, the posteriormost at the shoulder forming a small spine; interapertural area smooth, of only one part; tubes nearer to succeeding than to preceding varices, pointing abaxially, apically, and abaperturally; shoulder crossed by the former partitions; suture distinct; aperture ovate, pointing abapically, surrounded by a raised rim; anterior canal closed, narrow, long, slightly deflected to the right.

Holotype: Texas Bureau of Economic Geology no. 36638; height 14.6 mm, maximum diameter 8.4 mm.

Type locality: Texas BEG no. 113-T-19, one-half mile northeast of Wheeler Springs School, Houston County, Texas.

*Occurrence*: Weches Formation, Texas; Wautubbee Formation, Mississippi; early middle Eocene.

*Figured specimen*: BEG 36638 (holotype). Other occurrences: TU locality nos. 85, 86, 923, 924.

*Discussion*: This new species from the middle Eocene beds of Texas and Mississippi is the oldest known typhine in the New World. It is also the oldest known *Typhina* in the world and, as such, is marked by a multiwhorled protoconch, which seems to be a typical "primitive" character in the Muricidae (see Vokes, 1967, p. 135). This characteristic is further discussed in this paper under the genus *Siphonochelus*.

*T. palmerae* is not rare in the Wautubbee Formation of Mississippi, being represented by 14 specimens from 4 localities. The holotype is from the correlative Weches Formation of east Texas and is the only specimen from that formation.

The writer is pleased to name this new species after Dr. Katherine Van Winkle Palmer, of the Paleontological Research In-

stitution, in honor of her work on the Eocene faunas.

### Typhis (Typhina) mississippiensis Gertman, n. sp.

Plate 1, figs. 2a, b

*Description*: Shell moderate in size, stout; protoconch one and one-half whorls, smooth, polished, and rounded; four convex varices per whorl, each crossed by four crenulations, and with a spine at the apical end of the varix; outer lip crossed by four weak spiral ribs not much stronger than the axial growth lines; outer lip narrow and of even width, with a small partition crossing the shoulder; interapertural area of only one part; aperture elongate-ovate, pointed anteriorly, surrounded by a raised rim; tubes midway between varices, pointing abaxially, apically and abaperturally; shoulder slightly depressed and crossed by remnants of former partitions; suture distinct; anterior canal closed, broad, flattened, pointing to the right and abaperturally.

Holotype: USNM 646212; height 19.7 mm, maximum diameter 11.7 mm.

Type locality: TU 226, Chickasawhay River at Hiwannee (3½ miles south of Shubuta), Wayne County, Mississippi.

*Occurrence*: Red Bluff Clay, Mississippi; lower Oligocene.

*Figured specimen*: USNM 646212 (holotype).

*Discussion*: *T. mississippiensis* is recognized by the presence of four crenulations on the varices and four spiral ribs. It is a more inflated shell than the older *T. palmerae* but has a higher spire. It closely resembles *T. patellifer* Martin, 1931, from the upper Eocene of Java, differing principally in that the tubes in *T. mississippiensis* are directed abaperturally but in *T. patellifer* they are directed adaperturally.

This species is known only from the vicinity of the type locality. There are three specimens in the Tulane Collections from the type locality and others in the U. S. National Museum from Red Bluff, which is about two miles north of TU 226.

### Typhis (Typhina) siphonifer Dall

Plate 1, figs. 3a, b

*Typhis siphonifera* Dall, 1915, U. S. Natl. Mus., Bull. 90, p. 77, pl. 13, fig. 9.

Not *Typhis siphonifera* Dall. Anderson, 1929, California Acad. Sci., Proc., (Ser. 4) v. 18, no. 4, p. 138, pl. 9, fig. 8 (= *Typhis* [*Siphonochelus* (*Laevityphis*)] *costaricensis* Olsson, 1922).

*Typhis siphonifera* Dall. Mansfield, 1937, Florida Geol. Surv., Bull. 15, p. 135.

*Typhis* (*Typhinellus*) *siphoniferus* Dall. Keen, 1944, Jour. Paleontology, v. 18, no. 1, p. 56, 67.

"Shell small, short, stout-conic, of four whorls, of which the first is smooth and rounded, the others, rapidly enlarging, smooth, angulated by four varices about midway between which, on a subangular shoulder of the whorl, intervene stout tubes slightly backwardly and apically directed, entire and with subcircular orifices, one tube being situated in each interspace; suture distinct, deep, the whorl in front of it to the shoulder subtabulate, the shoulder rounded carinate, the whorl in front rapidly, flattishly attenuated; varices thin, recurved, between the shoulder and the canal with eight or nine crenulations between which and the margin of the aperture the front of the varix is somewhat convex and smooth; aperture rounded-ovate, with an entire, thin, projecting free margin; canal closed, short, stout, wide, slightly curved to the right and backward; siphonal fasciole with three projecting imbrications; the umbilical region deeply grooved, but not perforate." (Dall, 1915)

*Description*: Shell small; protoconch of one and one-half whorls, smooth and rounded; four varices per whorl; varices convex, weakly ribbed; outer lip narrow, weakly crenulated, narrowed above the aperture; a short, stout spine at the apical end of the varix; interapertural area of only one part; aperture small, rounded-ovate, surrounded by a raised rim; tubes midway between varices, pointing abaxially, apically and slightly abaperturally; shoulder raised, crossed by weak remnants of former partitions; suture distinct, deeply impressed; anterior canal closed, short, flattened, pointing to the right and abaperturally.

Holotype: USNM 165090; height 10.2 mm, maximum diameter 6.6 mm.

Type locality: Ballast Point, Tampa Bay, Florida.

*Occurrence*: Tampa Limestone, Florida; early lower Miocene.

*Figured specimen*: USNM 165090 (holotype).

*Discussion*: Dall (1915, p. 77) considered the Tampa Limestone from which the type specimen of *Typhis siphonifer* was collected to be Oligocene in age, but it is now generally accepted as being lower Miocene (Aquitanian). Keen (1944, p. 56) listed the species as Miocene and emended the name to *T. siphoniferus*. More recently (*in litt.*) she advised the writer that, as the generic name *Typhis* is considered masculine, the correct termination for this species should be *siphonifer*. Actually, a completely new name may be necessary for the species as there is a "*Murex*" *siphoniferus* Lesson,

1844 (Echo Monde Savant, v. 11, no. 24, p. 568), described from Acapulco, Mexico, which from the description is some species of Typhinae. The form was never figured and it is impossible to know exactly what typhine is being described. Therefore, no new name will be proposed for Dall's species inasmuch as it is possible that the genus to which Lesson's species is correctly to be referred is not *Typhis* s.s. but another typhine genus.

*Typhis siphonifer* should be placed in the subgenus *Typhina* because the varices are only slightly crenulated and the tubes are midway between the varices, rather than adapertural of the midpoint between the varices, their position in *Typhinellus*.

## Subgenus RUGOTYPHIS Vella, 1961

*Rugotyphis* VELLA, 1961, Palaeontology, v. 4, p. 376.
Type species: *Typhis francescae* Finlay, 1924, by original designation.

"Shell large for the subfamily, solid, with 4.2 growth steps per whorl; tubes directed radially or only slightly backwards, nearly horizontal; varices about midway between tubes, broad, elevated, with acute, foliated, crenulated crests, inclined away from the aperture, continued across the shoulder and contiguous with varices of previous whorl, forming four steep, sinistral spiral ridges from body to apex; apertural sides of varices ornamented with irregular, more or less radial ribs; reverse sides of varices and remainder of shell smooth except for growth lines; protoconch not seen." (Vella, 1961)

*Discussion*: Although *Rugotyphis* was erected for a species from the Miocene of New Zealand, many of the typhine species of the western Atlantic should be referred to this subgenus. It is distinguished from the other similar subgenera by having a large partition unlike *Typhinellus* and *Typhina*, but similar to that of *Talityphis*. It differs from *Talityphis* in lacking the expanded varical flange seen in that group as well as in *Typhina*, *Typhinellus*, and *Typhisopsis*, but has instead narrow crenulated varices. It differs from *Typhis* s.s. by having the large partition as well as by having the tubes almost perpendicular to the axis of the shell rather than parallel. There are two species known from the Miocene of New Zealand and all of the others are from the western Atlantic region, ranging from the upper Eocene Jackson Group to the Recent.

### TYPHIS (RUGOTYPHIS) DENTATUS Johnson

Plate 2, figs. 1a, b

*Typhis dentatus* JOHNSON, 1899, Acad. Nat. Sci. Phila., Proc., v. 51, p. 76, pl. 1, fig. 13.
*Typhis* (*Typhina*) *dentatus* Johnson. KEEN, 1944, Jour. Paleontology, v. 18, no. 1, p. 55, 64.
*Typhis* (*Typhina*) *dentatus* Johnson. PALMER *in* HARRIS and PALMER, 1947, Bulls. Amer. Paleontology, v. 30, no. 117, p. 344, pl. 45, fig. 25 (after Johnson).
*Typhis* (*Typhina*) *dentatus* Johnson. PALMER and BRANN, 1966, Bulls. Amer. Paleontology, v. 48, no. 218, p. 1009.

"Shell with seven whorls, including the two smooth apical whorls, each whorl with four varices or ribs, those of the body whorl serrated with six, partly open, teeth-like projections, the one at the shoulder large and irregular, the varices in all cases extend more than half-way up the spiral whorls, the large tubular spine at the shoulder midway between the varices extends outward and slightly forward, aperture ovate." (Johnson, 1899)

*Description*: Shell medium-sized; protoconch smooth, rounded, two whorls; five post-nuclear whorls; four flaring varices per whorl, each bearing six crenulations, that at the apical end of the varix curving apically and abaperturally; tubes midway between the varices, pointing abaxially and abaperturally; outer lip of constant width, a large partition, connecting the varix with that of the preceding whorl; aperture ovate, pointed anteriorly and surrounded by a raised rim; suture sharp, not appressed; interapertural area in two parts: the first including the tube and a small flange beyond it; the second with the remaining portion of the varix; anterior canal broad, closed, pointed slightly to the right and abaperturally; siphonal canal bearing remnants of earlier canals.

Holotype: ANSP 7049; height 15.0 mm, maximum diameter 9.5 mm.

Type locality: Jackson, Hinds County, Mississippi.

*Occurrence*: Moodys Branch Formation, Mississippi; upper Eocene.

*Figured specimen*: ANSP 7049 (holotype).

*Discussion*: This species, the oldest known *Rugotyphis*, is based on four specimens said to be from Jackson, Mississippi. No subsequent specimens have been found and the exact locality is not known.

*T. dentatus* closely resembles the younger *T. harrisi* Olsson from the upper Miocene beds of Florida, but may be distinguished by the almost smooth forward face of the apertural varix as opposed to the strongly ribbed varical face of all of the younger species such as *T. keenae* Gertman, n. sp., and *T. harrisi*.

### Typhis (Rugotyphis) keenae Gertman, n. sp.

Plate 2, figs. 2a, b, c; 3a, b

*Description*: Shell large; protoconch smooth, rounded, one and one-half whorls; five post-nuclear whorls; four flaring varices per whorl, each bearing four crenulations; the apical crenulation forming a spine at the top of the varix that curves apically and abaperturally; tubes midway between varices, pointing abaxially and abaperturally; outer lip of constant width around the aperture, joining the varix of the preceding whorl to form a partition on the shoulder; suture sharp, not appressed; aperture ovate, pointed anteriorly and surrounded by a raised rim; interapertural area in two parts: the first, beginning from the old aperture, under the tube, with three ribs close together; the second, on the back of the new varix and continuing over the varix, beginning with four ribs, the posterior rib continuing from the center area and turning apically to form the spine of the new varix; the middle two ribs beginning abruptly at the termination of the middle rib of the center area, and the last rib continuing from the anterior rib of the center area; the last three ribs continuing over the varix to the aperture, forming the three ribs on the front of the varix; some specimens marked with irregular, subdiagonal ridges forming a semi-reticulate pattern on the shell; anterior canal closed, short, narrow, pointing slightly to the right and abaperturally; siphonal canal bearing remnants of three earlier canals.

Holotype: USNM 646214; height 22.4 mm, maximum diameter 14.0 mm.

Paratype: USNM 646215; height 26.6 mm, maximum diameter 16.2 mm; locality TU 547.

Type locality: TU 458, east bank of Chipola River, above Farley Creek (SW ¼ Sec. 20, T1N, R9W), Calhoun County, Florida.

*Occurence*: Chipola Formation, Florida; late lower Miocene.

*Figured specimens*: Fig. 2, USNM 646215 (paratype). Fig. 3, USNM 646214 (holotype). Other occurrences: TU locality nos. 457, 546, 554, 555, 820, 821, 825, 827, 828, 951, 998.

*Discussion*: This new species from the Chipola Formation of northwestern Florida is unquestionably ancestral to *T.* (*Rugotyphis*) *harrisi* from the upper Miocene beds. *T.* (*R.*) *keenae* may be distinguished from the younger species by its heavier spiral ribbing, more constricted anterior canal, and stronger partitions on the shoulder. *T. harrisi* is widespread in the upper Miocene beds of Florida but *T. keenae* is confined to the Chipola Formation.

Although most examples of *T. keenae* possess smooth shells there are a few specimens from locality TU 547 that have an ornamentation rare among the Typhinae. The only comparable ornamentation is that found in the species referred to the subgenus *Pilsbrytyphis* Woodring, 1959. As the shells of that group are otherwise more closely related to *Siphonochelus* (*Laevityphis*) the presence of this ornamentation in a *Rugotyphis* apparently represents parallel evolution. It may be some type of environmental response, as the Chipola specimens with this ornamentation all occur at the same locality, which is a fossil coral reef. There are smooth shells found at the same locality so this ornamented shell can be regarded as an "ecotype" at best. The figured paratype (pl. 2, fig. 2) possesses this ornamentation.

It is a great pleasure to dedicate this new species to Dr. A. Myra Keen, the leading worker in the Typhinae.

### Typhis (Rugotyphis) harrisi Olsson

Plate 2, figs. 4a, b

*Typhis harrisi* Olsson, 1914, Bulls. Amer. Paleontology, v. 5, no. 24, p. 46, pl. 9, figs. 7, 9.

*Typhis harrisi* Olsson. Mansfield, 1930, Florida Geol. Surv., Bull. 3, p. 83, pl. 11, fig. 6.

*Typhis* (*Typhina*) *harrisi* Olsson. Keen, 1944, Jour. Paleontology, v. 18, no. 1, p. 55, 65.

> "Shell of moderate size; whorls polished; whorls about 5, with 4 large, thick varices, which on the body whorl extend completely across the whorl and onto the anterior canal; between these are shorter varices which continue only to just below the middle of the whorl; the varices carry on the shoulder of the whorls a hollow, recurved spine; these are generally broken off, and represented only by hollow stumps; whorls above the shoulder are irregularly flattened and with the suture appressed; on this area only the smaller varices continue across to the suture; surface of shell smooth with only growth lines which extend up onto the spines; the varix next to the mouth carries about four raised ridges which are placed at right angles to the aperture; on the body whorl resting marks are indicated by raised lines between the varices and representing the aperture and each of the larger varices have on their summit a wavy line formed by raised ridges corresponding to those at the aperture; canal broad and flattened, recurved and ending in hollow stump which probably represents the base of a recurved spine; aperture round or subovate with a raised rim." (Olsson, 1914)

*Description*: Shell large, stout; protoconch smooth, rounded, of one and one-half whorls; five post-nuclear whorls; four varices per whorl with a spine at the apical end of each varix; outer lip and varices crossed by three or four

ribs; outer lip of even width with a partition above the aperture, crossing the shoulder and connecting each varix with the varix of the preceding whorl; shoulder raised; suture distinct; interapertural area in two parts: the first including the tube and a small flange beyond it; the second including the rest of the varix; tubes closer to the preceding than the succeeding varix, pointing abaxially and abaperturally; shell smooth except for the crenulations on the varices; aperture rounded-ovate, large, and surrounded by a raised rim; anterior canal closed, broad, curving to the right and abaperturally.

Holotype: USNM 370190; height 19.1 mm, maximum diameter 12.8 mm.

Type locality: upper bed at Alum Bluff, Apalachicola River, Liberty County, Florida (= TU 72).

*Occurrence*: (?) "Silverdale Beds," North Carolina: early lower Miocene. Duplin Marl, North Carolina; Jackson Bluff Formation and Pinecrest Beds, Florida; upper Miocene.

*Figured specimen*: USNM 646216; height 24.3 mm, maximum diameter 16.0 mm; locality TU 60. Other occurrences: USGS Stations 3672, Hosford, Liberty County, and 8176, "Deadens" Washington County, Florida; Natural Well, North Carolina (= TU 376); TU locality nos. 562 (?), 712, 729, 730, 866 (?), 932.

*Discussion*: *T. harrisi* is one of the most widespread of the Miocene Typhinae. It occurs in the Duplin Marl of North Carolina and the Jackson Bluff Formation of northwestern Florida where it is moderately common (40 specimens from TU 60); but it is in the southern Florida Pinecrest Beds that it become truly abundant (360 specimens from 3 localities). At the latter localities it occurs with *T. floridanus*, its descendant form. It is possible to observe the gradual replacement of *T. harrisi* by *T. floridanus* at these Pinecrest localities. Along the Kissimmee River, on the north side of Lake Okeechobee, there is an excellent section "exposed" in the spoilbanks created by the U. S. Corps of Engineers in building the "Kissimmee Canal." From north to south the beds become progressingly younger, starting with the oldest beds exposed at the Seaboard Airline Railroad bridge at Fort Basinger (TU 730) and continuing until the Pliocene Caloosahatchee Formation is encountered at the bridge of Florida Highway 70 (TU 770). In the Tulane collections from the northernmost and oldest locality (TU 730) there are 128 specimens of *T. harrisi* but only three of *T. floridanus*. At the next locality farther south (TU 932) there are 75 *T. harrisi* to 20 *T. floridanus*. At the next locality (TU 729), which is a mixture of older strata and the "Brighton facies" of Olsson and Petit (1964, p. 517), actually the uppermost Pinecrest, there are 158 *T. harrisi* to 248 *T. floridanus*. From this point south only *T. floridanus* is found. Evidently *T. harrisi* is confined to the older Pinecrest and only *T. floridanus* occurs in the "Brighton facies." At other localities of this age which are not mixed with older strata (*e. g.*, TU 200, 520, 797) there are no *T. harrisi* found.

In the Tulane collections from the lower Miocene "Silverdale Beds" at Silverdale, North Carolina (Trent Marl of authors), there are two specimens that seem to be referable to *T. harrisi*. Due to the disjunct distribution in time it would seem unlikely that they are actually the same species as there have been no middle Miocene specimens of *T. harrisi* discovered as yet, but only more material can solve this problem.

## Typhis (Rugotyphis) floridanus Dall

Plate 2, figs. 5a, b; 6a, b

*Typhis floridanus* Dall, 1889, Harvard Mus. Comp. Zoology, Bull., v. 18, pt. 2, p. 216; 1890, Wagner Free Inst. Sci., Trans., v. 3, pt. 1, p. 152, pl. 9, fig. 5.

*Typhis floridanus* Dall. Woodring, 1928, Carnegie Inst. Washington, Publ. 385, p. 293.

*Typhis (Typhinellus) floridanus* Dall. Keen, 1944, Jour. Paleontology, v. 18, no. 1, p. 56, 64.

*Typhis (Typhinellus) floridanus* Dall. Olsson and Harbison, 1953, Acad. Nat. Sci. Phila., Monograph 8, p. 249, pl. 36, figs. 4, 4a, 4b.

*Typhis (Typhinellus) carolinensis* Olsson and Petit, 1964, Bulls. Amer. Paleontology, v. 47, no. 217, p. 551, pl. 81, figs. 1-1c.

"Shell of five or six whorls exclusive of the nucleus; spire short; varices on each whorl four, expanded, rather thin and sharp-edged, the whorl between flattish; at the shoulder the varix is produced into a slender twisted spine, not pervious, but with its distal end open and rarely perfect, turned toward the axis; whorl behind the shoulder irregularly flattened, appressed, but not much expanded at the suture; from the spine at the shoulder to the whorl between the varix is sometimes filled in by a thin shelly plate, and sometimes the plate is absent or obsolete; tubes moderate, situated midway between the varices or nearer the preceding varix, extending outward and backward; canal short, broad and flattened, with a small perforation; spiral sculpture of a few low ridges extending from the vicinity of the aperture to the summit of the varix, where they appear as serrations or abortive spines, but are obsolete behind the varix, or they

may be absent altogether; aperture subovate, simple, with a plain elevated rim." (Dall, 1890, p. 152)

*Description*: Shell large, elongate; protoconch bulbous, of one and one-half whorls; five post-nuclear whorls; four slightly crenulated varices per whorl, each crossed by nine ribs; a spine at the apical end of each varix pointing apically, axially, and then adaperturally; when broken the spines appear as hollow tubes, but do not connect with the interior of the shell, are flattened, and smaller in diameter than the tubes; tubes closer to preceding than succeeding varices, pointing abaxially, apically and abaperturally; varices only slightly convex; outer lip crossed by five ribs that connect with the rim of the aperture, three shorter ribs to the anterior of the aperture, and a short one to the posterior; outer lip of constant width; interapertural area of only one part; ribbing on the varices the only ornamentation; aperture ovate, surrounded by a raised rim; a partition above the aperture connecting the new varix to the varix of the preceding whorl; shoulder slightly raised, crossed by remnants of former partitions; suture distinct; anterior canal broad at its base, then tapering and turning slightly to the right and abaperturally.

Holotype: USNM 112184; height 14.7 mm, maximum diameter 7.9 mm.

Type locality: TU 536 (here designated), south bank of Caloosahatchee River about one mile east of LaBelle (Secs. 3 and 4, T43S, R29E), Hendry County, Florida. (Designated as type locality of the Caloosahatchee Formation by Olsson *in* Olsson and Petit, 1964, p. 519.)

*Occurrence*: Pinecrest Beds, Florida; upper Miocene. Caloosahatchee Formation, Florida; Waccamaw Formation, North and South Carolina; Pliocene.

*Figured specimens*: Fig. 5, USNM 646217; height 22.5 mm, maximum diameter 13.2 mm; locality TU 536. Fig. 6, USNM 646218; height 27.8 mm, maximum diameter 15.7 mm; locality TU 558. Other occurrences: TU locality nos. 79, 200, 202, 203, 519, 523, 527, 529, 532, 539b, 540, 579, 583, 726, 728, 729, 730, 736, 755, 767, 768, 769, 770, 792, 797, 870, 932, 939, 975.

*Discussion*: *T. floridanus* is most closely related to, and undoubtedly descended from, *T. harrisi* Olsson, from which it differs in being more elongate, with more numerous crenulations on the outer lip and varices. *T. harrisi* has four ribs crossing the varices, *T. floridanus* has five such ribs, and *T. puertoricensis* Warmke, 1964, the Recent member of the line, has six ribs.

Olsson and Petit (1964, p. 551) described a new species, *Typhis (Typhinellus) carolinensis*, as differing from *T. floridanus* "by its slimmer body whorl and larger size." The holotype and paratype are slightly larger than any specimens from the Caloosahatchee Formation but smaller topotypes in the Tulane collections agree perfectly with larger specimens of *T. floridanus*. Comparison of specimens of *T. carolinensis* with more than 1000 *T. floridanus* showed them to be well within the range of variation of whorl proportions for that species. Dall (1890, p. 152) noted "the older specimens [of *floridanus*] have a proportionally longer canal and less expanded varices, which makes them appear more slender than the young." No juvenile forms of *T. carolinensis* are reported, which leads the writer to conclude that the smaller specimens have been referred to *T. floridanus*. The type locality of *T. carolinensis* (TU 558) is remarkable for the large size attained by all of the shells found there. Specimens of *Oliva* from 80 to 90 mm in height are common, as are *Glycymeris americana* of over 100 mm in height.

## Typhis (Rugotyphis) puertoricensis Warmke

*Typhis (Talityphis) puertoricensis* Warmke, 1964, Nautilus, v. 78, no. 1, p. 1, pl. 1, figs. 1-4.

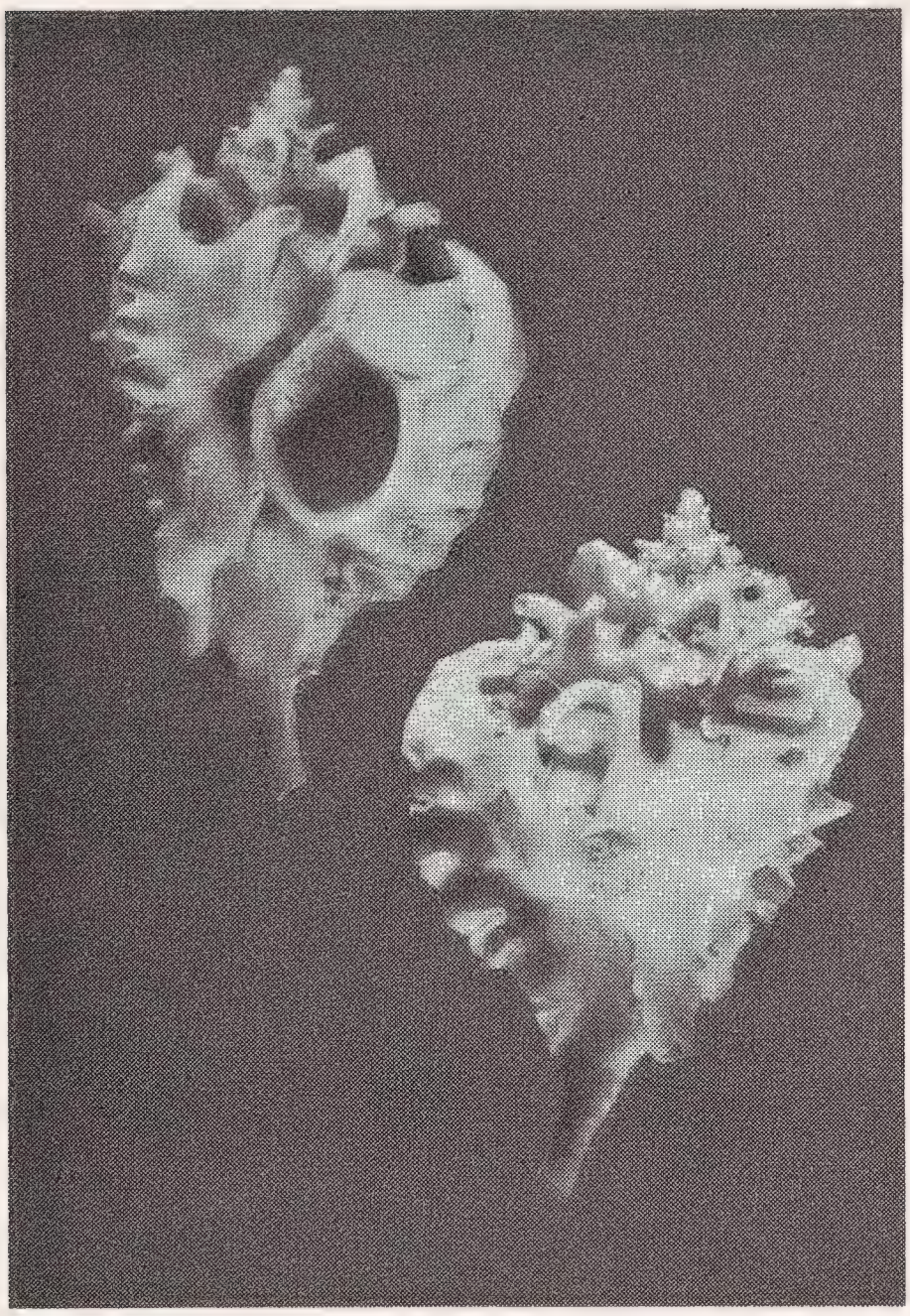
"Shell medium-sized, strong, rosy brown when young; later whorls whitish with a brownish-pink cast. Nucleus with two smooth and glassy whorls, followed by 5 gradually increasing whorls each bearing 4 cylinderical tubes alternating with the 4 rounded varices. Varices terminating in thin, recurved hooks. Tubes placed near the preceding varix, long and backward-pointing before breaking. Whorls parted by an increasing deep suture which is irregularly fluted by upper ends of recurved varices and bases of tubes. Surface sculptured with weak spiral cords that are more prominent on the varices, 6 being visible on the outer lip. Aperture small, oval, smooth internally; varix at outer lip greatly expanded and of nearly uniform width throughout. Suture line between outer lip and unsculptured pad [*i. e.*, partition] above aperture making a 45-degree angle with the sculpture of the outer lip. Anterior canal long, slender, closed in front; pillar with remains of three antecedent canals. Operculum unguiculate, with an apical nucleus." (Warmke, 1964)

Holotype: Stanford University Paleo. Type Coll. no. 9722; height 17.2 mm, maximum diameter 10.0 mm.

Type locality: Off Punta Cadena, north of Mayagüez, on the west coast of Puerto Rico, 33 fms.

*Occurrence*: Recent only, Caribbean Sea.

*Discussion*: This Recent member of the *T. harrisi-T. floridanus* lineage differs from



Text figure 2. *Typhis* (*Rugotyphis*) *cleryi* (Petit de la Saussaye). Holotype (× 3). Photograph courtesy of Muséum National d'Histoire Naturelle, Paris.

the fossil species in having more numerous, heavier spiral ribs. Otherwise the three forms are closely related.

TYPHIS (RUGOTYPHIS) CLERYI
(Petit de la Saussaye)
Text figure 2

*Murex* (*Typhis*) *cleryi* PETIT DE LA SAUSSAYE, 1840, Mag. Zool., v. 3, p. 327; 1842, *ibid.*, pl. 54.

Not *Typhis cleryi* (Petit). G. B. SOWERBY, JR., 1866, Thes. Conch., v. 3, *Typhis*, p. 320, pl. 284, fig. 14 (= *Typhis phillipensis* Watson, 1883).

*Murex cleryi* Petit. TRYON, 1880, Man Conch., v. 2, p. 137, pl. 30, fig. 301.

Not *Typhis cleryi* Sowerby. TRYON, 1880, Man. Conch., v. 2, p. 137, pl. 30, fig. 302 (after Sowerby, 1866, pl. 284, fig. 14, = *T. phillipensis* Watson).

Not *Typhis cleryi* Sowerby. SMITH, 1939, Cat. Recent species Rock shell, p. 18 (= *T. phillipensis*).

*Typhis* (*Typhinellus*) *cleryi* (Petit). KEEN, 1944, Jour. Paleontology, v. 18, no. 1, p. 56, 64.

"Testa pyriformi, rufescente, ventricosa, quadrifarium varicosa; varicibus terminatis in spinam subtilem et curvissimam desinentibus; anfractibus superne angulato-planulatis, spinis fistulosis subrectis, inter varices coronatis; spira exerta, acuta; apertura suborbiculari, producta; labro imbricato, fimbriato, externe reflexo; canali clauso, sobrecurvo, basi attenuato." (Petit de la Saussaye, 1840)

*Description*: Shell medium-sized, stout; five post-nuclear whorls; four convex varices per whorl; a spine at the top of each varix pointing apically and adaxially; outer lip of two parts; the inner part crossed by five strong ribs, the outer flange crenulate; interapertural area smooth under the tubes and strongly crenulated on the varices; tubes midway between the varices, pointing abaxially and abaperturally; aperture rounded-ovate; partition above the aperture equal in width to the outer lip, crossing the shoulder and joining the varix of the preceding whorl; shoulder slightly raised, suture distinct; anterior canal closed, narrow, pointing to the right and abaperturally.

Holotype: Muséum National d'Histoire Naturelle, Paris; height 18.5 mm, maximum diameter 11 mm.

Type locality: Cabo de São Tomé, [near Rio de Janeiro] Brazil, 40 fms.

*Occurrence*: Recent only, Brazil and West Africa.

*Figured specimen*: Holotype.

*Discussion*: *Typhis cleryi* is another descendant of the *T. harrisi* lineage but differs from *T. puertoricensis* in having a more inflated shell with less pronounced spiral ribs. In shape *T. cleryi* is closer to *T. harrisi* and *T. puertoricensis* is more like *T. floridanus*.

Although *T. cleryi* was described from off the Brazilian coast there is a specimen in the Tulane Collections from Rio de Oro, Spanish Sahara, northwestern Africa. There is also a magnificent specimen, 24 mm in height, in the collection of Crawford Cate, of Los Angeles, from off Mauritania, West Africa, in 33 fms.

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Subgenus TYPHINELLUS Jousseaume, 1880

*Typhinellus* JOUSSEAUME, 1880, Le Naturaliste, Année 2, no. 42, p. 335; 1882, Rev. Mag. Zool., (Ser. 3) v. 7, p. 337.

Type species: *Typhis sowerbiyi* [*sic*] Broderip, 1833 (= *T. sowerbii* Broderip).

"Coquille tétragone à spire élevée, conique, tours très déprimés près de la suture, armés de 4 varices ailées et d'un canal tubiforme intermédiaire; ouverture centrale petite, ovale, à bords détachés et continus; canal large et fermé." (Jouseaume, 1882)

Shell with four varices and tubes per whorl; tubes closer to preceding than succeeding varices, pointing abaxially and abaperturally; varix

at outer lip constricted above the aperture; flaring at anterior canal; faint spiral sculpture common.

*Discussion*: There are but four species of *Typhinellus* ranging in age from the lower Oligocene (Tongrian) to the Recent. The oldest known form is *T.* (*Typhinellus*) *tetrapterus protetrapterus* Sacco, 1904, from Italy. There is one species, *T. macropterus* Martin, 1884, from the Miocene of Java, and a single species from the Miocene Chipola Formation of Florida. The only Recent species is *T.* (*T.*) *sowerbii* Broderip, type of the genus, known previously from the Mediterranean Sea, but herein also reported from the Caribbean. This species has had two varieties named, neither of which is valid, and has, in addition, four synonyms, all from the Pliocene of Italy.

### Typhis (Typhinellus) chipolanus Gertman, n. sp.

Plate 1, figs. 4a, b

*Description*: Shell small, elongate; five post-nuclear whorls; protoconch smooth, rounded; four slightly convex varices per whorl; spine at top of each varix, curving axially and apically; tubes closer to preceding than succeeding varices, pointing apically, abaxially, and abaperturally; outer lip of two parts, an inner band and a weakly crenulated outer flange; outer lip wider than the partition above the aperture; shoulder crossed by remnants of former partitions, joining each varix to the varix of the preceding whorl; shoulder depressed slightly; suture distinct; aperture oval, surrounded by a raised rim; anterior canal long, narrow, pointing to the right and abaperturally.

Holotype: USNM 646213; height 12.5 mm, maximum diameter 6.7 mm.

Type locality: TU 547, west bank of Chipola River, about 2000 ft. above the mouth of Four Mile Creek (SW ¼ Sec. 29, T1N, R9W), Calhoun County, Florida.

*Occurrence*: Chipola Formation, Florida; late lower Miocene.

*Figured specimen*: USNM 646213 (holotype).

*Discussion*: All of the four known species of *Typhinellus* are so similar that they could well be placed in synonymy. This new species from the Chipola Formation is the oldest fossil *Typhinellus* from the New World and differs from the others in having a more elongate, narrower shape and a much wider siphonal canal. The species is based on a single specimen from a fossil coral reef (TU 547), which has many other unique species of mollusk also.

### Typhis (Typhinellus) sowerbii Broderip

Plate 1, figs. 5a, b, c

*Murex fistulatus* Risso, 1826, Hist. Nat. Eur. Mérid., v. 4, p. 191. Not *Muricites fistulatus* Schlotheim, 1820.

[?] *Murex labiatus* Cristofori and Jan, 1832, Cat. Mus., Sec. II, Conch. foss., p. 11 (nomen dubium).

*Typhis sowerbii* Broderip, 1833, Zool. Soc. London, Proc., pt. 2, p. 178.

*Murex tetrapterus* Bronn, 1838, Lethaea Geogn., v. 2, p. 1077, pl. 41, fig. 13a, b.

*Murex syphonellus* Bonelli *in* Bellardi and Michelotti, 1841, R. Acc. Sci. Torino, Mem., (Ser. 2) v. 3, p. 129, pl. 3, figs. 3, 4.

*Typhis sowerbii* Broderip. G. B. Sowerby, Jr., 1841, Conch. Illus., pl. 200, figs. 7, 8, and "var.," 9.

*Typhis sowerbyi* Broderip. H. and A. Adams, 1853, Genera Recent Mollusca, v. 1, p. 76, pl. 8, figs. 2 (animal), 2a, 2b (operculum), 2c (shell).

*Typhis tetrapterus* Bronn. Tryon, 1880, Man. Conch., v. 2, p. 136, pl. 30, figs. 290-292 (after Adams, 1853, pl. 8, figs. 2a, b, c.).

*Typhis sowerbyi fulva* Pallary, 1906, Jour. Conchyl., v. 54, p. 90.

*Typhis sowerbyi minor* Pallary, 1906, Jour. Conchyl., v. 54, p. 90.

*Typhis* (*Typhinellus*) *sowerbyi* Broderip. Smith, 1939, Cat. Recent species Rock shells, p. 19, pl. 14, fig. 12.

*Typhis* (*Typhinellus*) *sowerbyii* Broderip. Keen, 1944, Jour. Paleontology, v. 18, no. 1, p. 56, 67.

> "Typhis testa subovata, albida, quadri-vel quinque-fariam varicosa, varicibus laminatis subfrondentibus; tubulis suberectis; canali brevi, subrecurva, gracili." (Broderip, 1833)

*Description*: Shell medium-sized, elongate; protoconch smooth, rounded, of one and one-half whorls; five post-nuclear whorls; four smooth to weakly crenulated, convex varices per whorl; a spine at the top of each varix, pointing apically; outer lip of two parts: a weakly ribbed inner band of even width, and an outer flange, greatly flaring anteriorly and weakly crenulated; interapertural area smooth, divided only by the remnant of the outer lip flange at the edge of the varix; tubes closer to preceding than succeeding varices, pointing apically, abaxially, and abaperturally; aperture ovate, surrounded by a raised rim; partition above aperture narrower than outer lip, crossing the shoulder and joining the varix to the varix of the preceding whorl; shoulder depressed; suture distinct; anterior canal closed, narrow, curving sharply to the right and abaperturally.

Holotype: not found; height ⅞ inch, diameter ½ inch (*fide* Broderip, 1833).

Type locality: Mediterranean Sea.

*Occurrence*: (?) Matura shell bed, Trinidad; Astian Stage, Italy; Pliocene. Mediterranean and Caribbean Seas, Recent.

*Figured specimen*: USNM 696658; height 17.0 mm, maximum diameter 10.0 mm; locality, *Oregon* Station 5070.

*Discussion*: Although this species has long been known from the Mediterranean, this is the first report from the western Atlantic. The figured specimen was dredged by the U. S. Fish and Wildlife Service M/V *Oregon* near Nevis, Leeward Islands, at 50-60 fms. (*Oregon* Station 5070). One complete specimen plus some fragments were collected by the *Anton Bruun* Cruise 10, at Duarte Cay, north of Porto Bello, Panamá (TU R-100). Another specimen, owned by Mrs. Harold Rathburn of Sarasota, Florida, was dredged off Egmont Key, Florida, in 41 fms., and yet another, in the collection of Mrs. Mildred Tate, of Lake Jackson, Texas, came from 28 fms., off the Texas coast.

Keen (*in litt.*) is of the opinion that this species is not *T. sowerbii* but is new. Her reasons include "the difference in the shape of the anterior end of the aperture, the difference in the way the outer lip turns back, and the contrast in the relative sizes of the tube-spines and varices—the varices as seen in the apical view are relatively much smaller in your shell." The writer, however, feels that these differences are within the range of variation of *T. sowerbii*. More material may well prove him wrong.

As is shown by the synonymy above this species has many names. The earliest is *Murex fistulatus* Risso, 1826 (*fide* Fischer-Piette and Beigbeder, 1943, p. 326), which fortunately is preoccupied by *Muricites fistulatus* Schlotheim, 1820 (*vide* ICZN *Code*, Art. 56b). The second name is *Murex labiatus* Cristofori and Jan, 1832, which Keen (1944, p. 56) regarded as a *nomem dubium*. It is probable that the name *labiatus* was intended for the species subsequently named *T. tetrapterus*, for Cristofori and Jan described their form as "labro alato" with the type locality "C. arq." or Castellarquato, an Italian Pliocene locality where "*T. tetrapterus*" is common. However, *T. fistulosus* (Brocchi, 1814), the other species with which *labiatus* has been synonymized also is common at Castellarquato, so it seems best to follow Keen's suggestion and consider this name as a *nomen dubium*.

The original spelling of *T. sowerbii* without a "y" was used twice by Broderip and subsequently by Sowerby and it is assumed to be the correct original spelling. Presumably it was thought to be better Latin. Subsequent authors have emended this spelling to *sowerbyi*, as it was named for James Sowerby, but the *International Code of Zoological Nomenclature* states (Art. 32a) that the original spelling is to be retained unless it contraves one of the mandatory provisions of the *Code*, which this does not, or unless it is an obvious inadvertent error, which this also is not. In Appendix D of the *Code* (16b) this latinization is not recommended, but it is not forbidden.

As *T. tetrapterus* this species is widely reported in the Pliocene of Italy, but no attempt has been made to include these ref-

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PLATE 1

Figures


1. *Typhis* (*Typhina*) *palmerae* Gertman, n. sp. (× 3) ..... 148
   Texas BEG 36638 (holotype); height 14.6 mm, diameter 8.4 mm.
   Locality: Wheeler Springs, Texas. Weches Fm., middle Eocene.
2. *Typhis* (*Typhina*) *mississippiensis* Gertman, n. sp. (× 2) ..... 149
   USNM 646212 (holotype); height 19.7 mm, diameter 11.7 mm.
   Locality: TU 226. Red Bluff Clay, lower Oligocene.
3. *Typhis* (*Typhina*) *siphonifer* Dall (× 4) ..... 149
   USNM 165090 (holotype); height 10.2 mm, diameter 6.6 mm.
   Locality: Ballast Point, Tampa Bay, Florida. Tampa Limestone, lower Miocene.
4. *Typhis* (*Typhinellus*) *chipolanus* Gertman, n. sp. (× 4) ..... 155
   USNM 646213 (holotype); height 12.5 mm, diameter 6.7 mm.
   Locality: TU 547. Chipola Fm., lower Miocene.
5. *Typhis* (*Typhinellus*) *sowerbii* Broderip (× 3) ..... 155
   USNM 696658; height 17.0 mm, diameter 10.0 mm.
   Locality: *Oregon* Station 5070. Recent.

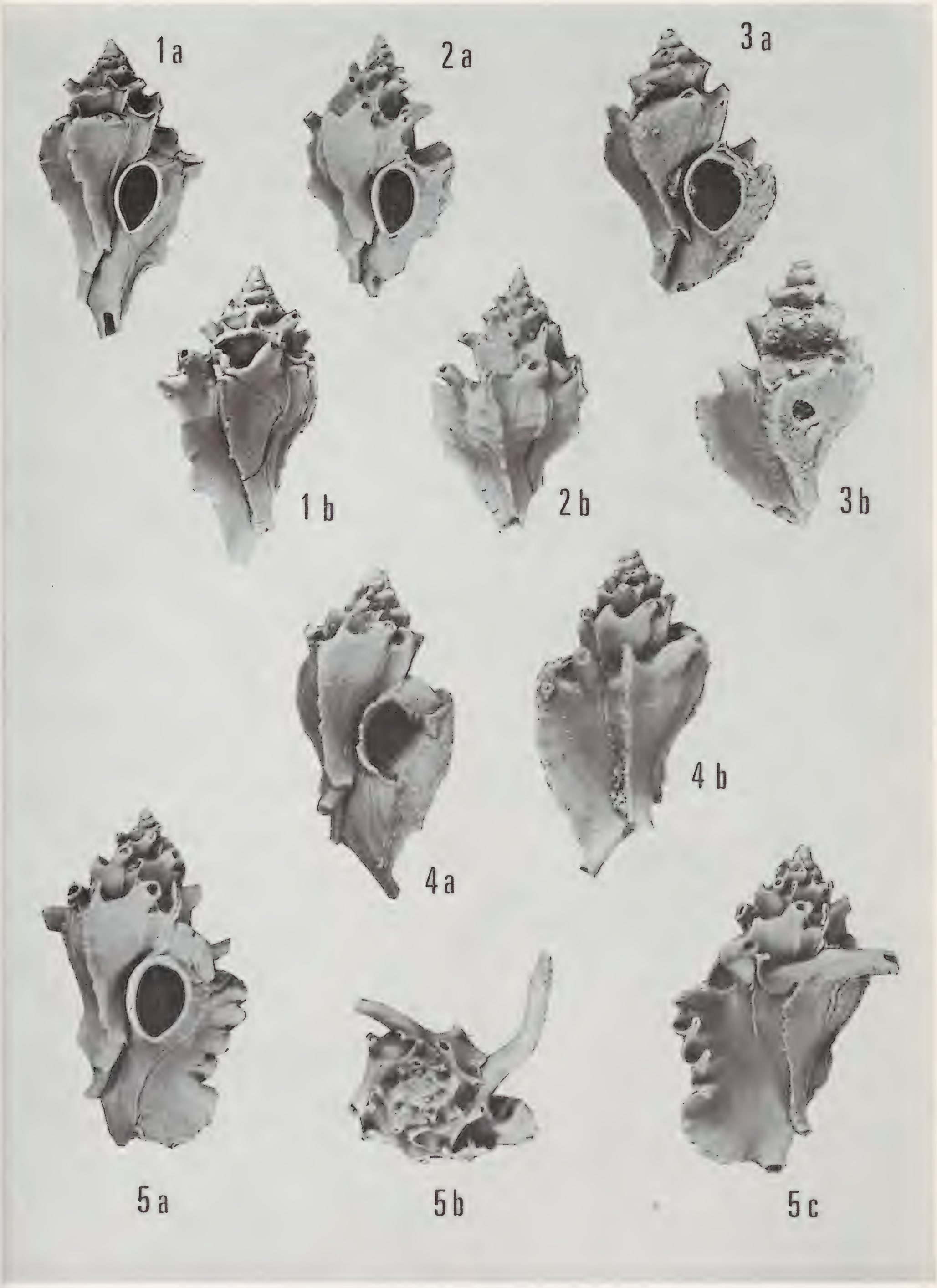


PLATE 1

erences in the synonymy above. It was reported from the Miocene of the Vienna Basin by Hörnes (1856, p. 263) but his figured specimen (*ibid.*, pl. 26, fig. 10) is not the same species, nor even the same subgenus.

In a recent paper Jung (1969, p. 493, pl. 50, figs. 5, 6) has reported a *Typhis* (*Typhinellus*) cf. *quadratus* Hinds from the Pliocene Matura shell bed of Trinidad. All of his specimens are said to be strongly worn and it is difficult to be certain of their identity. From the illustration the species seems to be *T.* (*T.*) *sowerbii*, a not entirely unexpected form connecting the occurrences in the Chipola Formation with the Recent Caribbean representatives.

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## Subgenus TALITYPHIS JOUSSEAUME, 1882

*Talityphis* JOUSSEAUME, 1882, Rev. Mag. Zool., (Ser. 3) v. 7, p. 338.

Type species: *Typhis expansus* Sowerby, 1874, by original designation.

"Coquille épaisse, turbinée, rappelant par la forme le *C.* [*Crassilabrum*] *Talienwahense*, à spire courte, tours ornés de varices frangées et recourbées en arrière, ne s'etendant pas sur le canal antérieur et d'un canal tubiforme intermédiaire placé près de la suture; ouverture ovale à bords continus, canal antérieur court, large à la base, étroit et déjeté à droite en avant." (Jousseaume, 1882)

Shell with four varices and tubes per whorl; tubes closer to preceding than succeeding varices, pointing abaxially, apically, and abaperturally; varix at outer lip greatly expanded, wide throughout, with a partition above the aperture; spiral sculpture may be present.

*Discussion*: *T. expansus*, the type species of *Talityphis*, was described without locality data. Keen (1944, p. 56) reported that Olsson collected specimens of *T. expansus* from Santo Domingo and this has been taken by subsequent authors to be the locality for the species. Keen did not locate the type specimen at the British Museum (Nat. Hist.) and it is presumed to be lost (Keen, personal communication). Several specimens have been dredged by the U. S. Fish and Wildlife Service M/V *Oregon* off the Surinam coast, which agree well with Sowerby's illustration and so, for the present, *T. expansus* is considered to be the correct name for the Caribbean species.

The 12 species of *Talityphis* range in age from lower Miocene to Recent, and are all found in the Americas. The oldest known species is from the lower Miocene (Aquitanian) of the Atlantic coast of Colombia and Trinidad (*T. precursor* Keen and Campbell, 1964). By middle Miocene time the subgenus had spread to California (*T. lampada* Keen, 1943) and throughout the Caribbean and Gulf region, as far north as Maryland. *T.* (*Talityphis*) *carmenae*, n. sp., is described herein from the upper Miocene of Mexico. *Typhis olssoni* Keen, 1943, the only representative of the subgenus in the Pliocene, is from western Costa Rica. There are two Recent species: *T. expansus* Sowerby, and *T. latipennis* Dall, 1919, from Baja California.

### TYPHIS (TALITYPHIS) PRECURSOR Keen and Campbell

Plate 3, figs. 1a, b; 2a, b

*Typhis alatus obesus* Gabb. MAURY, 1925, Bulls. Amer. Paleontology, v. 10, no. 42, p. 336, pl. 36, figs. 6, 9 (*not* of Gabb).

*Typhis* (*Talityphis*) *precursor* KEEN and CAMPBELL, 1964, Veliger, v. 7, no. 1, p. 49, pl. 9, figs. 14, 18, 21, 22.

"Shell large, exceptionally sturdy, with massive tubes and ridge-like varices; teleoconch whorls 5, spire relatively high; varices and tubes 4 per whorl; pad above aperture a little narrower than the outer lip portion of the varix; sculpture almost entirely axial, with weak spiral lines showing only on the face of the outer lip varix, which is festooned slightly by about 6 spiral lines; aperture relatively large, its margin free and entire, standing upward as an oval rim; anterior canal completely sealed along the apertural face, open at end." (Keen and Campbell, 1964)

Holotype: Univ. Calif. Dept. Paleo. Type Coll. no. 15083; height 47.5 mm, maximum diameter 31.0 mm.

Type locality: Univ. Calif. loc. S-8012, on the coast 6 km west of Puerto Colombia, Dept. Atlantico, Colombia.

*Occurrence*: Las Perdices Shale, Colombia; Manzanilla Formation, Trinidad; lower Miocene.

*Figured specimens*: Fig. 1, UCPDTC 15083 (holotype). Fig. 2, PRI 1057; height 29.0 mm, maximum diameter 20.0 mm; locality, Milepost 11 on Caparo Road, Trinidad (specimen figured by Maury, 1925, pl. 36, fig. 6, 9).

*Discussion*: Keen and Campbell (1964, p. 49) recently named a species from the Aquitanian beds of northern Colombia, which is the oldest *Talityphis* yet to be discovered. There is another very similar form of almost equivalent age from the lower Miocene Manzanilla Formation of Trinidad that was cited by Maury (1925, p. 336)

as "*T. alatus obesus*." Maury's specimen differs from *T. precursor* in having stronger spiral ornamentation but otherwise the two forms are almost identical. Considering the marked similarities and the nearly correlative ages, Maury's specimen is here referred to *T. precursor*.

This species is unique among the Typhinae in its extremely large size. The holotype of *T. precursor* is 47.5 mm and one hypotype measures 49 mm. This is the largest size ever reported for any species of Typhinae, fossil or Recent. Keen and Campbell (1964, p. 50) discussed the significance of this large size, stating: "The occurrence of a massive shell as the initial stock in a line is unusual in the history of most molluscan groups, for the trend normally is from rather unspecialized forms toward greater size or more elaboration. Here there is smoothness and solidity, and the direction taken by the *Talityphis* stock as it radiated northward, eastward, and northwestward during Miocene time was toward smaller, thinner shells, with a proportionately shorter spire and wider lip varix. The diamond shape of *T. precursor* persists in *T. pterinus* but is replaced by a more triangular outline in *T. lampada* Keen, 1943 from the California Miocene and *T. alatus* Sowerby, 1850 [*i.e.*, *T. obesus* Gabb] from the middle Miocene of the West Indies. In all of the species of *Talityphis*, the anterior canal and pillar area seems to be narrower and more tapering than in the closely related group, *T.* (*Typhisopsis*)."

Text figure 3. *Typhis* (*Talityphis*) *alatus* Sowerby. BM(NH) P.D.-GG 20084 (holotype) (× 2). Photograph courtesy of British Museum (Nat. Hist.)

## Typhis (Talityphis) alatus Sowerby

Text Fig. 3

*Typhis alatus* Sowerby, 1850, Geol. Soc. London, Quart. Jour., v. 6, p. 48, pl. 10, fig. 4.
*Typhis alatus* Sowerby. Guppy, 1876, Geol. Soc. London, Quart. Jour., v. 32, p. 522 (in part only).
Not *Typhis alatus* Sowerby. Brown and Pilsbry, 1911, Acad. Nat. Sci. Phila., Proc., v. 63, p. 354 (= *T. obesus* Gabb).
*Typhis alatus* Sowerby. Maury, 1917, Bulls. Amer. Paleontology, v. 5, no. 29, p. 100.
*Typhis alatus* Sowerby. Pilsbry, 1922, Acad. Nat. Sci. Phila., Proc., v. 73, p. 354.
*Typhis alatus* Sowerby. Keen, 1943, San Diego Soc. Nat. History, Trans., v. 10, no. 2, p. 33, 53.
*Typhis* (*Talityphis*) *alatus* Sowerby. Keen, 1944, Jour. Paleontology, v. 18, no. 1, p. 56, 63.

"Testa ovato-oblonga, subfusiformis, transversim striata, anfractibus senis, quadrifariam varicosis, costellis brevibus intermediis; varice ultimo lato, tenui, radiatim striato, canali longiusculo, obtecto.

"Distinguished by the tenuity and great extent of the wing-like varix from all known species." (Sowerby, 1850)

*Description*: Shell elongate; five post-nuclear whorls; four straight varices per whorl; outer lip of two parts: an inner band and a wide, thin, outer flange; a moderately long, recurved spine at shoulder of apertural varix, surrounded by outer lip; large partition, joining the varix to the varix of the preceding whorl; shell surface almost completely smooth, four very faint spiral lines, visible only on apertural face of varices; aperture small, circular, surrounded by a raised rim; tubes closer to the preceding than succeeding varices, pointing abaxially and abaperturally; shoulder depressed; anterior canal closed, narrow, straight.

Holotype: Brit. Mus. (Nat. Hist.) Paleo. Dept.-GG 20084; height 29.5 mm, maximum diameter 18.0 mm.

Type locality: Yaque River, Dominican Republic.

*Occurrence*: Unknown formation, Dominican Republic.

*Figured specimen*: BM(NH) P.D.-GG 20084 (holotype).

*Discussion*: Although this species has been synonymized with *T. obesus* Gabb the two forms are distinct. *T. alatus* is very rare, there being apparently only two examples known, the type and one immature specimen in the Gabb Collection at the Academy of Natural Sciences of Philadelphia (ANSP 3250). Maury's expedition (1917) to Santo Domingo uncovered no specimens and Woodring (1928, p. 294) stated that the U. S. Geological Survey party had not collected any specimens either. In Santo Domingo *T. obesus* is also rare, the type specimen being unique, neither Maury nor the U. S. G. S. discovering any specimens of this form. However, this species is common in other areas so that its variability is well known and the extremely attenuated *T. alatus* is not considered to be within the range of variation of *T. obesus*.

*T. alatus* is most closely related to the following undescribed species from Panamá, which is soon to be named by Woodring. *T. alatus* is smoother than the Panamanian form and the angle of the shoulder spine is different, but basically *T. alatus* is much more closely related to the Panamanian species than it is to *T. obesus*.

### Typhis (Talityphis) sp.

Plate 5, figs. 1a, b

*Description*: Shell elongate; protoconch of two and one-half smooth whorls; five postnuclear whorls; four straight varices per whorl, each varix crossed by five to eight weak ribs; outer lip wide, of two parts: a thick inner band and an outer flange that recurves abaperturally; a spine at apical end of the varix with a very expanded partition, almost twice the width of the outer lip, joining the varix to the varix of the preceding whorl; interapertural area of two parts: the area under the tube and the area forming the new varix; aperture small, ovate, surrounded by a raised rim; tubes closer to the preceding than succeeding varices, pointing abaxially and abaperturally; shoulder depressed; anterior canal closed, greatly narrowed, straight.

*Occurrence*: Gatun Formation, Panamá, middle Miocene.

*Figured specimen*: USNM 646221; height 17.7 mm, maximum diameter 9.2 mm; locality: TU 958.

*Discussion*: As this new species is soon to be described by Woodring (U. S. G. S. Prof. Paper 306-D, in press), it will only be cited here as "sp." In the interest of completeness it was felt necessary to include the form for comparison with *T. alatus*. There are several specimens known of this new species, all from near Cativa, Panamá.

### Typhis (Talityphis) obesus Gabb

Plate 4, figs. 1-4

*Typhis obesus* Gabb, 1873, Amer. Philos. Soc., Trans., (N.S.) v. 15, p. 203.

*Typhis alatus* Sowerby. Guppy, 1867, Sci.

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## Plate 2

Figures — Page

1. *Typhis (Rugotyphis) dentatus* Johnson (× 3) ..... 150
   ANSP 7049 (holotype); height 15.0 mm, diameter 9.5 mm.
   Locality: Jackson, Mississippi. Moodys Branch Fm., upper Eocene.
2-3. *Typhis (Rugotyphis) keenae* Gertman, n. sp. ..... 151
   (Fig. 2a, b—× 2; fig. 2c—× 4; fig. 3a, b—× 2)
   2. USNM 646215 (paratype); height 26.6 mm, diameter 16.2 mm.
      Locality TU 547. Chipola Fm., lower Miocene.
   3. USNM 646214 (holotype); height 22.4 mm, diameter 14.0 mm.
      Locality: TU 458. Chipola Fm., lower Miocene.
4. *Typhis (Rugotyphis) harrisi* Olsson (× 2) ..... 151
   USNM 646216; height 24.3 mm, diameter 16.0 mm.
   Locality: TU 60. Jackson Bluff Fm., upper Miocene.
5-6. *Typhis (Rugotyphis) floridanus* Dall (× 2) ..... 152
   5. USNM 646217; height 22.5 mm, diameter 13.2 mm
      Locality: TU 536. Caloosahatchee Fm., Pliocene.
   6. USNM 646218; height 27.8 mm, diameter 15.7 mm.
      Locality: TU 558. Waccamaw Fm., Pliocene.

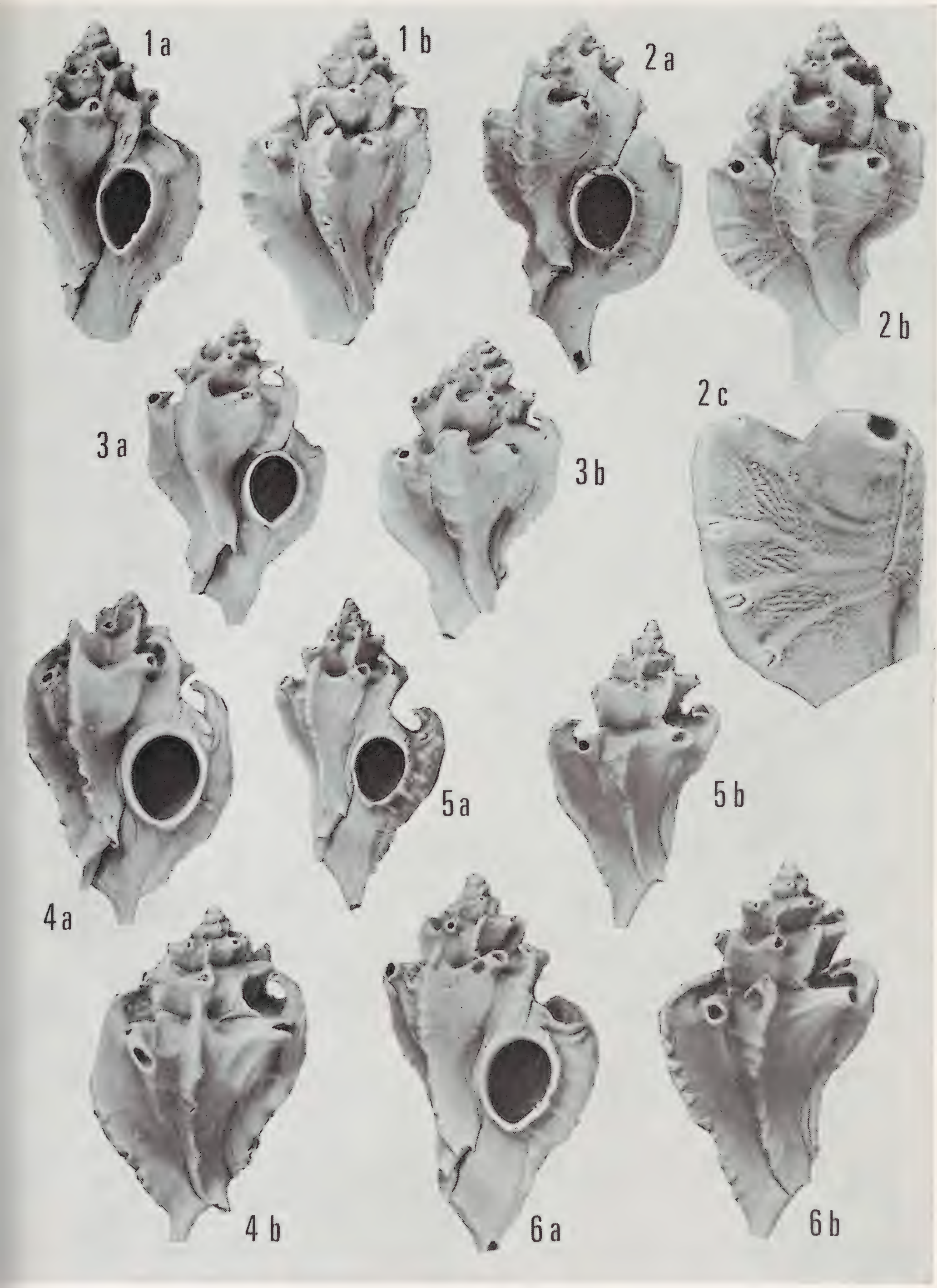


PLATE 2

Assoc. Trinidad, pt. 3, p. 157 (*ex* Harris reprint, 1921, Bulls. Amer. Paleontology, v. 8, no. 35, p. 184); 1873, *ibid.*, v. 2, p. 83 (*ex* Harris, *ibid.*, p. 215): 1876, Geol. Soc. London, Quart. Jour., v. 32, p. 522 (*not* of Sowerby).

*Typhis alatus obesus* Gabb. DALL, 1890, Wagner Free Inst. Sci., Trans., v. 3, pt. 1, p. 151.

*Typhis alatus* Sowerby. BROWN and PILSBRY, 1911, Acad. Nat. Sci. Phila., Proc., v. 63, p. 354 (*not* of Sowerby).

*Typhis obesus* Gabb. PILSBRY, 1922, Acad. Nat. Sci. Phila., Proc., v. 73, p. 354, pl. 28, figs. 5, 6 (holotype).

*Typhis alatus* Sowerby. OLSSON, 1922, Bulls. Amer. Paleontology, v. 9, no. 39, p. 132, pl. 10, fig. 15 (*not* of Sowerby).

Not *Typhis alatus obesus* Gabb. MAURY, 1925, Bulls. Amer. Paleontology, v. 10, no. 42, p. 336, pl. 36, figs. 6, 9 (= *Typhis precursor* Keen and Campbell, 1964).

*Typhis* (*Talityphis*) *alatus obesus* Gabb. WOODRING, 1928, Carnegie Inst. Washington, Publ. 385, p. 294, pl. 18, figs. 3, 4.

*Typhis alatus obesus* Gabb. KEEN, 1943, San Diego Soc. Nat. Hist., Trans., v. 10, no. 2, p. 33, 53, pl. 3, figs. 13, 18, 22.

*Typhis* (*Talityphis*) *obesus* Gabb. KEEN, 1944, Jour. Paleontology, v. 18, no. 1, p. 56, 66.

*Typhis* (*Talityphis*) *alatus obesus* Gabb. GARDNER, 1947, U. S. Geol. Surv. Prof. Paper 142-H, p. 527, pl. 53, figs. 15, 16.

*Typhis* (*Talityphis*) *alatus obesus* Gabb. WOODRING, 1959, U. S. Geol. Surv. Prof. Paper 306-B, p. 221, pl. 31, figs. 3, 4.

*Typhis* (*Talityphis*) *alatus* Sowerby. OLSSON, 1964, Neogene Mollusks from Northwestern Ecuador, p. 141 (*not* of Sowerby).

> "Shell short, broad; spire very low; whorls eight, sharply angulated; concave above the suture, sloping convexly below; varices four to each whorl, acute-angular on their margins, and ending in a blunt process on the upper angle of the whorl; tubes moderate, pointed laterally, below each tube the surface of the shell is greatly swollen, and two lines pass anteriorly, one being the margin of the old mouth, the other, in advance of the tube, being similar in character and indicating another arrest in growth. Surface polished, marked by faint lines of growth, and crossed below the angle by a few irregular transverse lines, not ribs. Aperture small, oval, bordered by a prominent, acute raised margin; canal closed, short, recurved; front face of terminal varix marked by five small ribs radiating from the outer lip." (Gabb, 1873)

*Description*: Shell large, stout; six postnuclear whorls; four convex varices per whorl, crossed by five weak ribs; outer lip of constant width, greatly expanded, consisting of an inner band, and an outer flange; aperture large, ovate, surrounded by a raised rim; tubes closer to preceding than succeeding varices, pointing abaxially, apically, and abaperturally; a partition above the aperture crossing the shoulder and joining the varix to the varix of the preceding whorl; shoulder slightly concave, crossed by remnants of the partitions; suture distinct; interapertural area of three parts: the area under the tube; the wide flange of the new varix, formed with five ribs and a short blunt spine at the apical end; and, the inner band formed within the flange of the varix and crossed by five ribs; anterior canal closed, short, and broad, pointing to the right and abaperturally.

Holotype: ANSP 3251; height 24.8 mm, maximum diameter 18.4 mm.

Type locality: Dominican Republic.

*Occurrence*: Chipola Formation, Florida; late lower Miocene. Unknown formation, Dominican Republic and Haiti; middle Miocene. Gatun Formation, Panamá and Costa Rica; middle Miocene. Picaderos Formation, Ecuador; middle or upper Miocene. Bowden Formation, Jamaica; (?) upper Miocene. (?) Matura Formation, Trinidad; Pliocene.

*Figured specimens*: Fig. 1, ANSP 3251 (holotype). Fig. 2, USNM 646219; height 18.0 mm, diameter 13.8 mm; locality TU 554. Fig. 3, USNM 369461, height 23.7 mm, diameter 17.0 mm; locality, Bowden, Jamaica. Fig. 4, USNM 646220; height 27.5 mm, diameter 23.0; locality TU 757. Other occurrences: TU locality nos. 70, 196, 456, 457, 458, 546, 547, 655, 705, 786, 806, 817, 818, 819, 820, 821, 825, 827, 830, 950, 951, 958, 998.

*Discussion*: In 1873 Gabb reported a new species, *Typhis obesus*, from Santo Domingo, which, he stated, was similar in some respects to *T. alatus* Sowerby from the same area. Guppy (1876, p. 522), after examining both specimens, commented that *T. obesus* "is not specifically distinct from *T. alatus*." Subsequent workers have usually treated the short, stout *T. obesus* as a subspecies of the tall, thin *T. alatus*, but there seems little necessity to make such an assignment. The resemblances between the two forms are subgeneric rather than specific in nature. At none of the many other western Atlantic localities where *T. obesus* occurs in abundance, such as in the Chipola Formation of Florida and the Gatun Formation of Panamá, is there any great variation in spire height and all specimens found are referable to *T. obesus*, none to *T. alatus*.

*T. obesus* is the most widespread typhine species in the Miocene beds of the western Atlantic. The type of the species is from the middle Miocene of Santo Domingo. Guppy (1876) reported it from Haiti and Jamaica in the Miocene, and Pliocene of Trinidad. Dall (1890) and Gardner (1947) reported it from the late lower Miocene Chipola Formation of northwestern Florida. Brown and Pilsbry (1911) first noted its

appearance in Panamá, and Olsson (1922) and Woodring (1959) further documented this. In the Tulane collections from Panamá there are numerous specimens. Olsson (1964) reported "*T. alatus*" in the middle or upper Miocene Picaderos Formation of northwestern Ecuador and also included the species found at Puerto Limon, Costa Rica, with this form. However, the latter is *T. expansus*.

There is a direct line of descent from *T. obesus* to the Recent *T. expansus*, the only difference being that *T. expansus* has a much higher spire than *T. obesus* (this does not, however, make it the same as *T. alatus* as has been suggested by authors). The shell figured by Woodring from Bowden, Jamaica (here refigured in pl. 4, fig. 3), is intermediate in shape between the middle Miocene *T. obesus* and the Pleistocene and Recent *T. expansus*. The outline is closer to that of *T. obesus* than to *T. expansus* and it is included with that species. The writer has not seen specimens of what Guppy called "*T. alatus*" from the Pliocene of Trinidad but it may well also be *T. expansus*.

### Typhis (Talityphis) pterinus Gardner

Plate 5, figs. 2a, b

*Typhis pterinus* Gardner, 1936, Florida Geol. Surv., Bull. 14, p. 52, pl. 10, fig. 10.
*Typhis pterinus* Gardner. Keen, 1943, San Diego Soc. Nat. Hist., Trans., v. 10, no. 2, p. 33, 53.
*Typhis (Talityphis) pterinus* Gardner. Keen, 1944, Jour. Paleontology, v. 18, no. 1, p. 56, 66.
*Typhis (Talityphis) pterinus* Gardner. Gardner, 1947, U. S. Geol. Surv. Prof. Paper 142-H, p. 528, pl. 53, fig. 14.

"Shell polished, of moderate dimensions for the genus, rather thin and quite slender excepting for the flange-like varices; spire scalariform; body including the varices cuneate; maximum diameter falling a little in front of the median horizontal. Whorls of conch probably 6 in number in the adult, very closely appressed, the posterior margin creeping up a little upon the preceding whorl, acutely angulated at the periphery. Shoulder slightly concave, more or less corrugated by the intervarical tubes; sides of whorls flattened, slightly inclined toward the axis; body somewhat rounded medially, gently concave anteriorly. Sutures linear, inconspicuous zigzaging around the varices. Protoconch known only from the final whorl but apparently small, smooth, and very highly polished. Opening of conch indicated by a change in the texture of the shell and by the initiation of the axial sculpture in the form of obtuse tubercles. Primary varices 4 in number, the terminal varix a rather broad, laminar flange, the other 3 body varices compressed, acutely angulated ridges, terminating at the shoulder in compressed, posteriorly directed tubes; short circular tubes also developed in the intervarical areas directed at right angles to the axis of the shell, perforate at their outer extremities but only the last tube in direct communication with the body cavity. Spiral sculpture restricted to very fine, feeble, rather distant, and more or less irregular lirations, often obsolete altogether upon the spire, strengthening toward the aperture and usually 3 to 5 in number upon the terminal wing, absent upon the anterior canal. Incremental macroscopic, retractive and somewhat arcuate upon the shoulder, flexuous upon the anterior canal and relatively prominent upon the apertural surface of the terminal varix, where they are quite strongly crenulated and are puckered into the fine, sharp spiral lirae. Apertural opening rather small, oval in outline, widening a little posteriorly, the margin elevated slightly above the body surface; peristome continuous, smoothly rounded; inner surface very smoothly glazed; area between the labral varix and that directly behind it filled with a rather thin, trigonal plate. Anterior canal short, compressed, feebly inclined toward the right, the former canals, one to each varix, superimposed but diverging very slightly at their anterior extremities." (Gardner, 1936)

Holotype: USNM 371860; height 18.8 mm, maximum diameter 12.5 mm.

Type locality: Shell Bluff, Shoal River, Walton County, Florida (= TU 69).

*Occurrence*: Shoal River Formation, Florida; middle Miocene.

*Figured specimen*: USNM 371860 (holotype). Other occurrences: TU locality nos. 69, 69A.

*Discussion*: *T. pterinus* is closely related to *T. carmenae* Gertman, n. sp. It differs in having fewer but stronger spiral ribs. *T. pterinus* is known only from the vicinity of the type locality but it is fairly abundant there. There are 21 specimens from the two localities listed.

### Typhis (Talityphis) acuticosta (Conrad

Plate 3, figs. 3a, b; 4a, b

*Murex acuticosta* Conrad, 1830, Acad. Nat. Sci. Phila., Jour., (Ser. 1) v. 6, p. 211, 217, pl. 9, fig. 1.
*Typhis acuticosta* (Conrad). Conrad, 1833, Amer. Jour. Sci., (Ser. 2) v. 23, p. 344; Conrad, 1861, Fossils of the Medial Tertiary of the United States, no. 4, p. 83, pl. 48, fig. 1; 1863, Acad. Nat. Sci. Phila., Proc., v. 14,

p. 560; 1868, Amer. Jour. Conch., v. 4, p. p. 64, pl. 5, fig. 6.
*Typhis acuticosta* (Conrad). DALL, 1890, Wagner Free Inst. Sci., Trans., v. 3, pt. 1, p. 151.
*Typhis acuticosta* (Conrad). HARRIS, 1893, Amer. Jour. Sci., (Ser. 3) v. 45, p. 30.
*Typhis acuticosta* (Conrad). MARTIN, 1904, Maryland Geol. Surv., Miocene, p. 201, pl. 51, figs. 1-3.
*Typhis harrisi waltonensis* MANSFIELD, 1935, Florida Geol. Surv., Bull. 12, p. 38, pl. 5, fig. 9.
*Typhis* (*Typhina*) *harrisi waltonensis* Mansfield. KEEN, 1944, Jour. Paleontology, v. 18, no. 1, p. 55, 68.
*Typhis* (*Typhina*) *acuticosta* (Conrad). KEEN, 1944, Jour. Paleontology, v. 18, no. 1, p. 68.

"Shell with four or five acute foliated varices ending above in a pointed, compressed spire, alternating with four shorter rounded varices ending above in a tube; aperture oval and entire; margin reflected; beak closed, and slightly recurved." (Conrad, 1830)

*Description*: Shell large, stout; five postnuclear whorls, with four smooth, thickened, convex varices per whorl; outer lip narrow, of even width with a partition above the aperture crossing the shoulder and joining the varix to the varix of the preceding whorl; a short, blunt spine at the apical end of the varix; interapertural area of only one part; surface of the shell smooth; aperture ovate, pointed anteriorly, surrounded by a raised rim; tubes midway between varices, pointing apically, and abaperturally; shoulder raised, crossed by remnants of former partitions; suture distinct, deeply impressed; anterior canal closed, narrow, rounded, pointing to the right and abaperturally.

Holotype: ANSP 13615; height 24.5 mm, maximum diameter 14.0 mm.

Type locality: Maryland.

*Occurrence*: Calvert Formation, Choptank Formation, and St. Mary's Formation, Maryland; Choctawhatchee Formation, Florida; middle Miocene.

*Figured specimens*: Fig. 3, ANSP 13615 (holotype). Fig. 4, USNM 373146 (holotype-*T. harrisi waltonensis* Mansfield); height 17.5 mm, maximum diameter 11.0 mm; locality, Vaughan Creek, Walton County, Florida.

*Discussion*: *T. acuticosta* was named without any precise locality or stratigraphic data. It has been reported from the St. Mary's, Choptank, and Calvert formations of Maryland so that the type locality cannot be deduced. In addition to the Maryland localities the species also occurs in the late middle Miocene Choctawhatchee Formation of Florida, where it was given the name "*T. harrisi waltonensis*" by Mansfield. Although made a subspecies of *T. harrisi* by Mansfield the two forms are only generically related. Mansfield did not compare his new subspecies with *T. acuticosta* but only noted that the two forms are "closely related." Examination of the two type specimens fails to reveal any specific differences between them and the two are here placed in synonymy.

## TYPHIS (TALITYPHIS) SIPHON Woodring

Plate 3, figs. 5a, b

*Typhis* sp., DALL, 1903, Wagner Free Inst. Sci., Trans., v. 3, pt. 6, p. 1584 (list).
*Typhis* (*Typhinellus*) *siphon* WOODRING, 1928, Carnegie Inst. Washington, Publ. 385, p. 293, pl. 18, fig. 2.

→

PLATE 3

Figures — Page

1-2. *Typhis* (*Talityphis*) *precursor* Keen and Campbell ..... 158
1. (× 1¼) UCPDTC 15083 (holotype); height 47.5 mm, diameter 31.5 mm.
Locality: Near Puerto Colombia, Dept. Atlantico, Colombia. Las Perdices Shale, lower Miocene.
2. (× 1½) PRI 1057; height 29.0 mm, diameter 20.0 mm.
Locality: Trinidad. Manzanilla Fm., lower Miocene.

3-4. *Typhis* (*Talityphis*) *acuticosta* (Conrad) (× 2) ..... 163
3. ANSP 13615 (holotype); height 24.5 mm, diameter 14.0 mm.
Locality: Maryland. Unknown formation, middle Miocene.
4. USNM 373146 (holotype—*T. harrisi waltonensis*); height 17.5 mm, diameter 11.0 mm.
Locality: Vaughan Creek, Walton Co., Florida. Choctawhatchee Fm., middle Miocene.

5. *Typhis* (*Talityphis*) *siphon* Woodring (× 3) ..... 164
USNM 115495 (holotype); height 15.6 mm, diameter 8.9 mm.
Locality: Bowden, Jamaica. Bowden Fm., (?) upper Miocene.

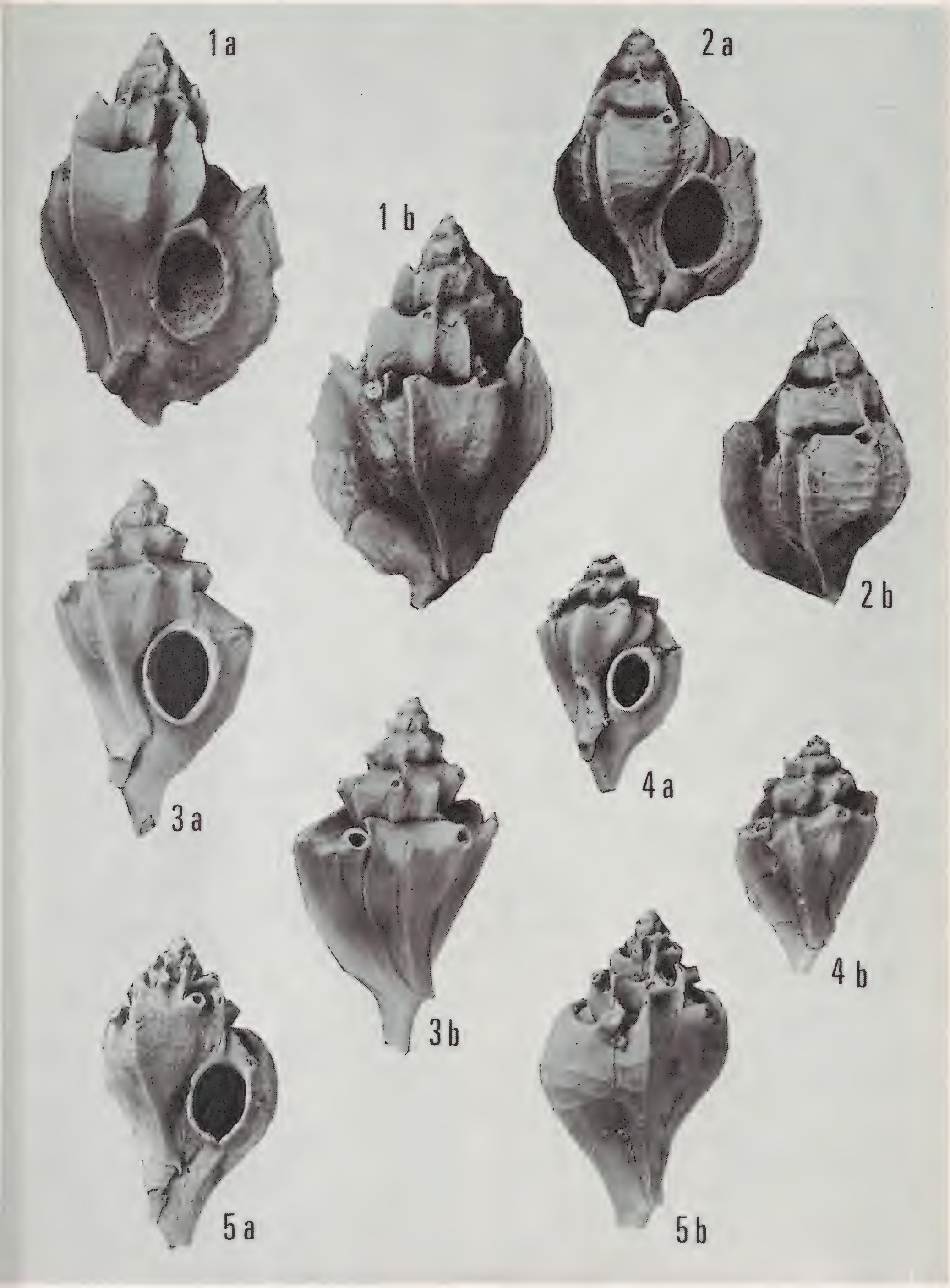


PLATE 3

*Typhis* (*Typhinellus*) *siphon* Woodring. KEEN, 1944, Jour. Paleontology, v. 18, no. 1, p. 56, 67.

"Shell relatively small, Varix at outer lip slightly expanded. Body whorl bearing five [four] lamellar varices that bear at shoulder an upturned and incurved spine. On latter part of body whorl several indistinct widely spaced spiral threads are visible. Low triangular partitions extend from tubules about halfway up preceding whorl, joining the tubules to a varix." (Woodring, 1928)

*Description*: Shell small, elongate; five postnuclear whorls; four smooth convex varices per whorl; varices thin and sharp, giving the shell an angular appearance; outer lip smooth, narrow, and constricted above the aperture; interapertural area of only one part with two weak spiral ribs below tubes, bifurcating to four on the varices; aperture small, ovate, surrounded by a raised rim; tubes closer to preceding than succeeding varices; pointing abaxially and abaperturally; shoulder slightly depressed, crossed by remnants of former weak partitions; suture distinct; anterior canal closed, flattened, pointing to the right and abaperturally.

Holotype: USNM 115495; height 15.6 mm, maximum diameter 8.9 mm.

Type locality: Bowden, Jamaica (= TU 705).

*Occurrence*: Bowden Formation, Jamaica; (?) upper Miocene.

*Figured specimen*: USNM 115495 (holotype). Other occurrences: TU locality 705.

*Discussion*: *T. siphon* is represented by only four immature specimens from the Bowden Formation of Jamaica, two in the type lot and two in the Tulane collections from Bowden. It was compared by Woodring to *T.* (*Rugotyphis*) *floridanus* Dall but differs from that species in lacking the crenulated varices typical of the *Rugotyphis* group. Although the extant specimens of *T. siphon* do not possess the wide winged varices of the typical *Talityphis*, as noted by Woodring, the specimens are juveniles and resemble the usual juvenile *Talityphis* condition. This species does not seem to be closely related to any other Caribbean form.

In the original description of the species Woodring noted that the body whorl had "five lamellar varices." The writer believes that he included the last varix of the preceding whorl in his count; the type specimen has but four varices. He followed the same procedure in his discussion of "*Typhis*" (*Pilsbrytyphis*) *gabbi*, Brown and Pilsbry (1959, p. 220), herein referred to *Siphonochelus* (*Pilsbrytyphis*).

## TYPHIS (TALITYPHIS) CARMENAE Gertman, n. sp.

Plate 5, figs. 3a, b; 4a, b

*Description*: Shell medium-sized, stout; protoconch smooth, bulbous, of one and one-half whorls; six post-nuclear whorls; four convex varices per whorl; each varix crossed by seven ribs; outer lip wide, of two parts: an inner band, and an outer flange that curls abaperturally; flange smooth on the ventral side, but a continuation of the varix on the dorsal side, and crossed by seven ribs; a spine at the apical end of the varix; a small partition above the aperture, crossing the shoulder and joining the varix to the varix of the preceding whorl; aperture small, ovate, surrounded by a raised rim; tubes closer to the preceding than the succeeding varices, pointing abaxially and abaperturally; shoulder slightly depressed; interapertural area of four parts: the area under the tube divided into two parts, each with nine ribs; the ribs offset, not forming continuous ridges; the third part forming the new varix, having nine ribs that are offset from those in the area under the tube, the apertural side of the flange smooth and forming the outer margin of the outer lip; the fourth part with nine ribs that cross the inner part of the outer lip to the aperture; outer flange of lip broken off after the varix is abandoned, and ribbing appears continuous on the remnant varices; anterior canal closed, broad, curving abaperturally to the right.

Holotype: USNM 646222; height 20.6 mm, maximum diameter 12.6 mm.

Paratype: Instituto de Geología, Universidad de Mexico (UNAM) no. IGM-2186; height 27.3 mm, maximum diameter 18.5 mm. Locality: Paso Real, near Tuxtepec, Oaxaca, Mexico.

Type locality: TU 638; roadcut and quarry on Mexico Highway 180, 14 miles east of junction with side road into Coatzacoalcos, Veracruz, Mexico.

*Occurrence*: Agueguexquite Formation, Mexico; upper Miocene.

*Figured specimens*: Fig. 3, USNM 646222 (holotype). Fig. 4, IGM-2186 (paratype).

*Discussion*: *T. carmenae* is the last of the high-spired, highly ornamented line of *Talityphis*. The Recent member of the line is a high spired descendant of the smooth *T. obesus* group. This new species is most closely related to the older *T. pterinus* from the middle Miocene Shoal River Formation of Florida but differs in having more numerous spiral ribs.

*T. carmenae* is common at the type locality with there being 33 specimens in the type lot. In addition, in the collections of the Instituto de Geología, Universidad de Mexico (UNAM), there are two specimens, both larger than any from

the type locality. One of these is here figured as a paratype. The exact age of the beds at Tuxtepec, where these larger specimens occur, is not known but there are many species in common with the Agueguexquite localities near Coatzacoalcos and it is assumed that the two occurrences are directly correlative.

This new species is named in honor of Carmen Perrilliat Montoya, in recognition of her work on the fauna of the Agueguexquite Formation.

TYPHIS (TALITYPHIS) EXPANSUS Sowerby

Plate 5, figs. 5a, b; 6a, b

*Typhis expansus* G. B. SOWERBY, JR., 1874, Zool. Soc. London, Proc. (for 1873), p. 719, pl. 59, fig. 4; 1874, Conch. Icon., v. 19, *Typhis*, pl. 3, fig. 12a, 12b; 1880, Thes. Conch., v. 3, *Typhis* (supplement), pl. 284-b, figs. 24, 25.

*Typhis expansis* [*sic*] Sowerby. TRYON, 1880, Man. Conch., v. 2, p. 138, pl. 30, fig. 306 (after Sowerby, 1874, fig. 12b).

*Typhis melloleitaoi* MORRETES, 1940, Arq. Zool. Estdo. São Paulo, v. 2, art. 7, p. 251, pl. 1, figs. 1-3 (juvenile specimen).

*Typhis* (*Talityphis*) *expansus* Sowerby. KEEN, San Diego Soc. Nat. Hist., Trans., v. 10, no. 2, p. 53, pl. 3, fig. 20; KEEN, 1944, Jour. Paleontology, v. 18, no. 1, p. 56.

*Typhis alatus* Sowerby. OLSSON, 1964, Neogene Moll. Northwestern Ecuador, p. 141 (in part, *not* of Sowerby).

*Typhis alatus* Sowerby. BULLIS, 1964, Tulane Stud. Zool., v. 11, no. 4, p. 107.

> "T. testa subfusiformi, albida, pallide fusco tincta; spira breviuscula, acuminato-turrita; anfractibus transversim obscure liratis, superne angulatis, supra angulum concavis, quadrivaricosis; varicibus tenuibus, ad angulum falcatis, varice ultimo late expanso reflexo; tubis inter varices brevibus, ultima elongata; canali breviusculo; apertura ovali." (Sowerby, 1874)

*Description*: Shell large, stout; protoconch of one and one-half smooth, bulbous whorls; five post-nuclear whorls; four convex varices crossed by four weak ribs; outer lip wide, of two parts: an inner band and an outer flange that curls abaperturally; a spine at the top of the apical end of the varix; a partition above the aperture crossing the shoulder and joining the varix to the varix of the preceding whorl; interapertural area smooth under the tubes and ribbed on the varices; aperture ovate, surrounded by a raised rim; tubes closer to preceding than succeeding varices, pointing abaxially, abaperturally, and apically; shoulder depressed slightly; anterior canal closed, narrow, curving abaperturally and to the right.

Holotype: not found.

Type locality: Paramaribo, Surinam (Dutch Guiana) (here designated).

*Occurrence*: Moín Formation, Costa Rica; Pleistocene. Caribbean Sea, Recent.

*Figured specimens*: Fig. 5, USNM 646223; height 25.7 mm, maximum diameter 18.0 mm; locality TU 954. Fig. 6, USNM 696659; height 21.5 mm, maximum diameter 14.0 mm; locality, *Oregon* Station 2331. Other occurrences: TU locality no. 953.

*Discussion*: *T. expansus* was named by Sowerby without locality data, but there seems little doubt that the Caribbean shell figured herein is the same species. In the original description the shell was said to be whitish, tinged with brown and this matches our specimens exactly. Bullis (1964, p. 107) reported this species (as *T. alatus*) dredged by the M/V *Oregon* at two stations off the Surinam Coast in 24 and 30 fathoms. The locality of our figured specimen (*Oregon* Station 2331) is here designated as the type locality for *T. expansus*.

In addition to the Recent occurrences of this species, several specimens have been collected from the Pleistocene Moín Formation of Costa Rica. One of these is figured here (pl. 5, fig. 5).

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Genus SIPHONOCHELUS Jousseaume, 1880

Subgenus SIPHONOCHELUS s.s.

*Siphonochelus* JOUSSEAUME, 1880, Le Naturaliste, Année 2, no. 42, p. 335.
Type species: *Typhis avenatus* [*sic*] Hinds, 1843 (= *T. arcuatus* Hinds), by original designation.

*Cyphonochelus* JOUSSEAUME, 1882, Rev. Mag. Zool., (Ser. 3) v. 7, p. 337. Emendation?
Type species: *Typhis arcuatus* Hinds, by original designation.

*Trubatsa* DALL, 1889, Harvard Mus. Comp. Zool., Bull, v. 18, p. 216.
Type species: *Typhis* (*Trubatsa*) *longicornis* Dall, 1888, by monotypy.

*Choreotyphis* IREDALE, 1936, Australian Mus., Records, v. 19, no. 5, p. 324.
Type species: *Typhina* (*Choreotyphis*) *pavlova* Iredale, by original designation.

*Eotyphis* TEMBROCK, 1963, Paläontologische Abh., v. 1, no. 4, p. 322.
Type species: *Typhis sejunctus* Semper, 1861, by original designation.

> "Coquille ovale courte, dont le canal tubiforme postérieur est soudé aux varices au lieu de leur être intermédiarires comme dans les autres genres; ouverture petite, ovale, à bords continus et détachés; canal court assez large à la base. (Jousseaume, 1882)

Shell with four varices and tubes per whorl (one species with five); tubes formed within the varix, pointing abaperturally and abaxially; varix smooth and rib-like, no spines, flanges, or other ornamentation; no spiral sculpture.

*Discussion*: *Siphonochelus* is known from the Oligocene to Pliocene of Europe, and from the Miocene to Recent of the Australasian area. There is a single Miocene species and a single Recent species from the western Atlantic. In general the Recent species occur in deeper water than other species of Typhinae, most of the records being greater than 100 fms. Only the type is somewhat shallower, being known from 40 to 50 fms.

There have been a number of taxa proposed for species that are to be referred to *Siphonochelus*. The first of these was named by Dall (1889) who, after unmercifully castigating Jousseaume for naming "eleven unnecessary synonyms" of *Typhis*, proceeded to name another one which was an unequivocal synonym of one of Jousseaume's genera. Dall included Jousseaume's type species, *T. arcuatus* Hinds, in his new subgenus so it is obvious that he was cognizant of the synonymy but chose rather to ignore it. Dall also made the odd observation that the species of *Trubatsa* were found "in all the northern oceans," overlooking the fact that *T. arcuatus* was described from the Cape of Good Hope. Since Dall's time six more species have been described from the southern oceans. One of these was named as the type of another subgenus, *Choreotyphis* Iredale. This species is unique for the extremely long tube and canal it possesses. It does not differ significantly from the typical *Siphonochelus* but is merely a deep water form.

More recently Tembrock (1963) has named another subgenus, *Eotyphis*, which can be regarded as a synonym of *Siphonochelus*. Tembrock differentiated this subgenus because of the differences in the nuclear whorls of the fossil species and the Recent species of *Siphonochelus*. Her species of *Eotyphis* have from 2½ to 5¼ whorls in the embryonic shell, in general decreasing through time. She noted that according to Thorson this would indicate a pelagic larval stage for the older species as opposed to non-pelagic larvae of the modern species. This trend in decrease of nuclear whorls appears frequently in the Muricidae (see Vokes, 1967, p. 135) and does not seem to be of supraspecific significance.

Tembrock originally named *Eotyphis* as a subgenus of *Lyrotyphis* Jousseaume, 1880, as both forms possess multiwhorled protoconchs. *Lyrotyphis*, here treated as a subgenus of *Siphonochelus*, consists of only two European Oligocene species that have the tubes greatly appressed so that they are soldered to the preceding whorl. These two species also have five tubes to a whorl but this is not thought to be a distinguishing character as there is a Japanese species, *S. japonicus* (A. Adams, 1863), which has five tubes per whorl but otherwise is a good *Siphonochelus*.

### SIPHONOCHELUS (SIPHONOCHELUS) CERCADICUS (Maury)

Plate 6, figs. 1a, b

*Typhis cercadicus* MAURY, 1917, Bulls. Amer. Paleontology, v. 5, no. 29, p. 265, pl. 42, fig. 12.

*Typhis cercadicus* Maury. WOODRING, 1928, Carnegie Inst. Washington, Publ. 385, p. 294.

*Laevityphis* (*Laevityphis*) *cercadicus* (Maury). KEEN, 1944, Jour. Paleontology, v. 18, no. 1, p. 59, 64.

"Shell small, each whorl with four varices and four tubes, the tubes arising slightly behind the varices; on the last whorl are faint indications of about six raised spiral lines; the whorls are shouldered and the varices end at the shoulder; canal wide, covered, former position of canal indicated

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PLATE 4

Figures Page

1-4. *Typhis* (*Talityphis*) *obesus* Gabb (× 2) ..... 160

1. ANSP 3251 (holotype) height 24.8 mm, diameter 18.4 mm.
   Locality: Dominican Republic. Unknown formation, middle Miocene.
2. USNM 646219; height 18.0 mm, diameter 13.8 mm.
   Locality: TU 554. Chipola Fm., lower Miocene.
3. USNM 369461; height 23.7 mm, diameter 17.0 mm.
   Locality: Bowden, Jamaica. Bowden Fm., (?) upper Miocene.
4. USNM 646220; height 27.5 mm, diameter 23.0 mm.
   Locality: TU 757. Gatun Fm., middle Miocene.

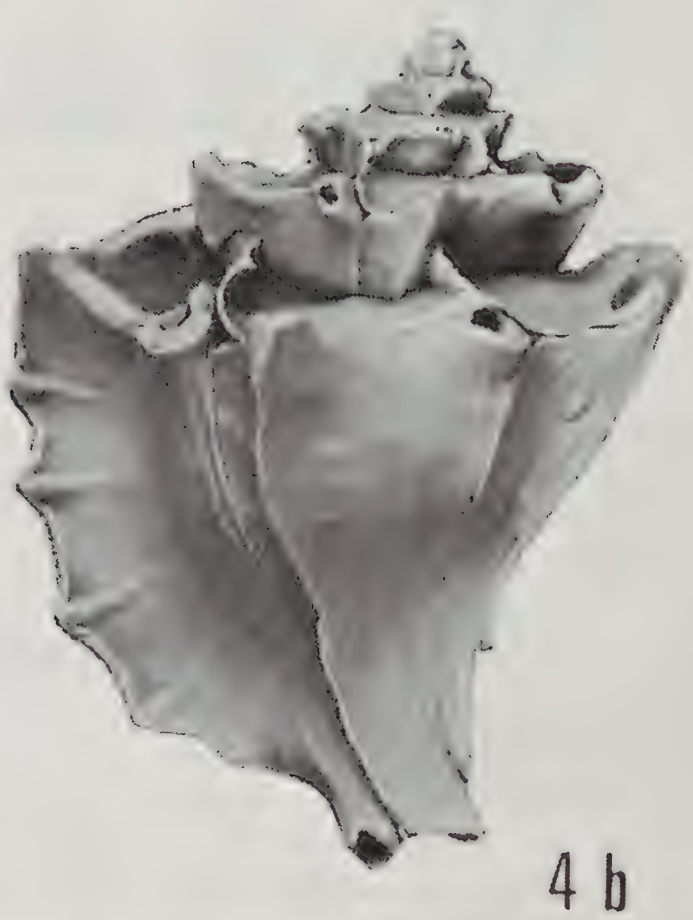


PLATE 4

by a tubular process beside the canal." (Maury, 1917)

*Description*: Shell small, stout; four post-nuclear whorls; four smooth rounded, convex varices per whorl; outer lip smooth, narrow, and of constant width; interapertural area of only one part; tubes attached to varices, pointing abaxially, apically, and abaperturally; shell smooth; aperture rounded-ovate, surrounded by a raised rim; outer lip narrowing above the aperture; shoulder raised; suture distinct; anterior canal closed, short, narrow, pointing to right and abaperturally.

Holotype: Cornell Paleo. Lab. no. 36813; height 6.6 mm, maximum diameter 3.9 mm.

Type locality: Bluff no. 1, Cercado de Mao, Dominican Republic.

*Occurrence*: Gurabo Formation,, Dominican Republic; middle Miocene.

*Figured specimen*: Cornell Paleo. Lab. no. 36813 (holotype).

*Discussion*: The only extant specimen of *S. cercadicus* is the holotype, a small specimen with only four post-nuclear whorls and undoubtedly a juvenile. Nevertheless it is a good *Siphonochelus* and as such is the only known example in the fossil record of the western Atlantic.

### SIPHONOCHELUS (SIPHONOCHELUS) LONGICORNIS (Dall)

*Typhis longicornis* DALL *in* AGASSIZ, 1888, Harvard Mus. Comp. Zool., Bull., v. 15, pt. 2, p. 70, fig. 294.

*Typhis* (*Trubatsa*) *longicornis* Dall. DALL, 1889, Harvard Mus. Comp. Zool., Bull., v. 18, p. 216, pl. 15, fig. 7; pl. 38, fig. 5.

*Typhis* (*Trubatsa*) *longicornis* Dall. SMITH, 1939, Cat. Recent species Rock shells, p. 19, pl. 14, fig. 10.

*Siphonochelus* (*Siphonochelus*) *longicornis* (Dall). KEEN, 1944, Jour. Paleontology, v. 18, no. 1, p. 58, 65.

"Shell translucent white when young, waxen with areas of pale rosy brown between the varices in the adult; varices four, ascending the spire nearly in a straight line; tubes tapering, recurved, usually broken off short, but originally long; nucleus subglobular, glassy, followed by seven gradually increasing whorls, obscured by the varices, but somewhat scalar behind; surface with extremely fine spiral striation, stronger lines of growth, and on the tips of the tubes and canals when fresh a glassy polish; varices not fimbriated, with rounded edges, strongly arched forward, subconcave behind; aperture small, subcircular, margin detached from the body, elevated, not sharp; with simple edge and smooth interior; canal long, slender, nearly straight, but bent back as a whole, with three antecedent canals surrounding a sort of umbilical chink. Operculum muricoid." (Dall, 1889, p. 216)

Holotype: Harvard MCZ 3717; height 23.0 mm, maximum diameter 10.0 mm.

Type locality: Off Havana, Cuba, in 127-400 fms.

*Occurrence*: Recent only, Florida Straits.

*Discussion*: *S. longicornis* is one of the deeper water typhine species, described from off Cuba. It is closely related to *S. arcuatus* (Hinds), the type of the genus, and could be just a deep water form of that species.

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## Subgenus LAEVITYPHIS Cossmann, 1903

*Laevityphis* COSSMANN, 1903, Essais Paléoconch. Comp., v. 5, p. 59.

Type species: *Typhis coronarius* Deshayes, 1865 (= *Typhis muticus* J. Sowerby, 1834), by original designation.

*Neotyphis* VELLA, 1961, Palaeontology, v. 4, no. 3, p. 375.

Type species: *Typhis tapunagai* Fleming, 1943 (emended, Vella, 1961), by original designation.

"Taille petite; forme oblongue, assez élancée; spire allongée, étagée aux sutures; tours lisses, un peu convexes, se recouvrant parfois en arrière, à sutures profondément canaliculées sous le recouvrement; quatre varices lisses, tranchantes, épineuses en arrière; tubulures non situées au milieu de l'intervalle des varices, chacune étant plus rapprochée de la varice suivante. Dernier tour presque égal aux deux tiers de la hauteur totale, ovale, peu excavé à la base, lisse comme la spire. Ouverture ovale, petite, à péristome continu, sans gouttière postérieure, auguleuse en avant, vers le point de soudure de ses bords; canal clos, assez long, large et peu infléchi, détaché du bourrelet basal qui porte des lamelles correspondant aux varices; labre vertical, bordé par la dernière varice, lisse à l'intérieur; columella excavée, lisse, à bord complètement détaché." (Cossmann, 1903)

Shell with four varices and tubes per whorl; tubes nearer to succeeding than preceding varices, but not attached to the varices, pointing apically or abaperturally; varices slightly crenulated or smooth, thickened, generally a spine at the shoulder of the varix.

*Discussion*: Cossmann (1903) originally described *Laevityphis* as a "section" of the subgenus *Typhina*. Keen noted that a few species of *Laevityphis* are difficult to discriminate from *Siphonochelus*, but as *Indotyphis* seems to be a subgroup of *Laevityphis*, she proposed that *Indotyphis* be made a subgenus of the genus *Laevityphis*, which she assigned equal rank with the genus *Siphonochelus*. The writer cannot

agree with this ranking, but prefers to place *Laevityphis* as a subgenus of *Siphonochelus* in view of the great similarity between the two forms. The principal difference in the two is that in *Siphonochelus* the tubes are incorporated into the varix but in *Laevityphis* they are distinct.

Vella (1961) proposed *Neotyphis*, a subgenus of *Typhis*, which he stated superficially resembled *Laevityphis* but which was actually closer to *Typhis* s.s. The differences he cited are also seen in well preserved specimens of *S.* (*Laevityphis*) *gracilis* (Conrad), an Eocene species considered by Cossmann to be a "pleisotype" of *Laevityphis* (as *L. alternata* Lea, a synonym of *L. gracilis*) and *Neotyphis* is not considered to be distinct from *Laevityphis*.

Sixteen species of *Laevityphis* are known, ranging in age from lower Eocene to Recent. The oldest known Typhinae (lower Eocene) is a *Laevityphis*, *S. muticus* (J. Sowerby, 1834), of England and France (*S. coronarius* is a synonym). Three species are known from the middle Eocene and by this time they were widely distributed: *S. sinuosus* (Cossmann, 1902) and *S. vaquezi* Cossmann, 1906, France; and *S. gracilis* (Conrad, 1833), Alabama. Another species, *S. antiquus* (Gabb, 1864), is from either the middle or upper Eocene of California. Two other species have been reported from upper Eocene strata: *S. thagus* (Olsson, 1930), Peru; and *S. ludbrookae* (Keen and Campbell, 1964), Australia. The only member of the subgenus known from the Oligocene is *S. curvirostratus* (Conrad, 1848), from Mississippi and Mexico. In the Miocene, *Laevityphis* became widespread in the Caribbean and Gulf of Mexico. From the Miocene strata we have: *S. linguiferus* (Dall, 1890), Florida; *S. costaricensis* (Olsson, 1922), Costa Rica and Colombia; *S. sawkinsi* (Mansfield, 1925), Trinidad; and *S. schencki* (Keen and Campbell, 1964), Colombia. There is a single species known from the Pleistocene of Costa Rica and the Recent Caribbean, *S. bullisi*, n. sp., described herein. There are two other Recent species only, one from East Africa, and one from the Indian Ocean and Japan.

There are seven species of *Laevityphis* in the western Atlantic region, ranging in age from middle Eocene to Recent.

## SIPHONOCHELUS (LAEVITYPHIS) GRACILIS (Conrad)

Plate 6, figs. 2a, b

*Typhis gracilis* CONRAD, 1833, Amer. Jour. Sci., v. 23, p. 344.
*Murex alternata* LEA, 1833, Contributions to Geology, p. 157, pl. 5, fig. 163.
*Typhis alternata* (Lea). DE GREGORIO, 1890, Ann. Géol. Paléontologie, livr. 7, p. 96, pl. 7, figs. 38-40.
*Typhis alternata* (Lea). COSSMANN, 1893, Ann. Géol. Paléontologie, livr. 12, p. 32.
*Typhis gracilis* Conrad. HARRIS, 1895, Acad. Nat. Sci. Phila., Proc., v. 47, p. 21.
*Murex alternata* Lea. HARRIS, 1895, Acad. Nat. Sci. Phila., Proc., v. 47, p. 4 (in synonomy with *T. gracilis* Conrad).
*Typhis* (*Typhina*, sect. *Laevityphis*) *alternatus* (Lea). COSSMANN, 1903, Essais Paléoconch. Comp., v. 5, p. 59, pl. 2, fig. 26.
*Typhis gracilis* Conrad. WRIGLEY, 1930, Malac. Soc. London, Proc., v. 19, pt. 3, p. 114.
*Typhis gracilis* Conrad. PALMER, 1937, Bulls. Amer. Paleontology, v. 7, no. 32, p. 271, pl. 36, figs. 1, 5; pl. 85, fig. 12.
*Laevityphis* (*Laevityphis*) *gracilis* (Conrad). KEEN, 1944, Jour. Paleontology, v. 18, no. 1, p. 59, 65.
*Laevityphis* (*Laevityphis*) *gracilis* (Conrad). PALMER and BRANN, 1966, Bulls. Amer. Paleontology, v. 48, no. 218, p. 716.

"Shell fusiform, elongated, slender, volutions about eight; ribs of the body whorl 4, thickened and slightly reflected; with two or three arched scales on each; margin of the aperture elevated but not reflected." (Conrad, 1833)

*Description*: Shell medium-sized, very elongate; protoconch one and one-half whorls, smooth, rounded; six post-nuclear whorls, with four convex varices per whorl; varices crossed by three weak crenulations, a spine at the top of each varix pointing axially and abaperturally; outer lip smooth, of even width on the outer margin, but narrowing above the aperture; interapertural area of only one part; aperture elongate-ovate, pointed at the anterior end, surrounded by a raised rim; tubes closer to the succeeding than the preceding varices, pointing apically and abaperturally; surface of shell smooth except for the crenulations on the varices; shoulder raised; suture distinct; anterior canal closed, long, narrow, pointing abaxially and abaperturally.

Lectotype: ANSP 13755; height 16.8 mm, maximum diameter 8.1 mm (selected by Moore, 1962, p. 63).

Type locality: Claiborne Bluff, Alabama River, Monroe County, Alabama (= TU 78).

*Occurrence*: Gosport Sand, Alabama; late middle Eocene.

*Figured specimen*: ANSP 13755 (lectotype). Other occurrences: TU locality nos. 78, 306.

*Discussion*: *S.* (*Laevityphis*) *gracilis*, the oldest species of *Laevityphis* in the western

Atlantic, is closest in form to *S. muticus* (J. Sowerby), from the Eocene of England, from which the former differs by its more elongate, slender shape, and crenulated varices. *S. thagus* (Olsson), upper Eocene, Peru, and *S. antiquus* (Gabb), middle or upper Eocene, California, have a similar shape, but have smooth varices as *S. muticus*.

### SIPHONOCHELUS (LAEVITYPHIS) CURVIROSTRATUS (Conrad)

Plate 6, figs. 3a, b

*Typhis curvirostratus* CONRAD, 1848, Acad. Nat. Sci. Phila., Proc., v. 3, p. 285; 1848, Acad. Nat. Sci. Phila., Jour., (Ser. 2) v. 1, p. 116, pl. 11, fig. 29.

*Laevityphis* (*Laevityphis*) *curvirostratus* (Conrad). KEEN, 1944, Jour. Paleontology, v. 18, no. 1, p. 59, 64.

*Typhis curvirostratus* Conrad. GARDNER, 1945, Geol. Soc. Amer., Mem. 11, p. 189, pl. 14, figs. 1, 2.

> "Subfusiform; volutions 8, scalariform, varices or ribs profound; tubes long; that near the margin of aperture, thick, elongated, beak elongated spiniform, much curved. Length 1-10 [? 7-10]. Not common." (Conrad, 1848)

*Description*: Shell medium-sized, stout; protoconch smooth, rounded, one and one-half whorls; six post-nuclear whorls; four thickened, convex, smooth varices per whorl; outer lip of constant width, with a short spine at the apical end of the varix; interapertural area of one part; aperture ovate, surrounded by a raised rim; a partition above the aperture connecting the varix to the varix of the preceding whorl; tubes closer to the succeeding than the preceding varices, pointing outward from the shoulder; very weak spiral ribbing on the varices; shoulder slightly depressed, crossed by remnants of former partitions; suture distinct; anterior canal closed, narrow, pointing abaperturally and to the right.

Lectotype: ANSP 13484; height 18.0 mm, maximum diameter 10.6 mm (selected by MacNeil *in* Moore, 1963, p. 52).

Type locality: Vicksburg, Mississippi.

*Occurrence*: Mint Springs Marl and Byram Marl, Missisippi; unnamed formation, Nuevo León, Mexico; middle Oligocene.

*Figured specimen*: ANSP 13484a (lectoparatype); height 19.8 mm, maximum diameter 12.2 mm. Other occurrences: TU locality nos. 76, 335, 336.

*Discussion*: *S.* (*Laevityphis*) *curvirostratus* is similar to, and may be descended from *S. muticus* (Sowerby) from the lower Eocene of England, which species may also be the forerunner of *S. gracilis* (Conrad) and *S. thagus* (Olsson). The latter species, from the upper Eocene of Peru, is more slender and elongate, with smooth convex varices. Of the Miocene forms, *S. curvirostratus* is most like *S. sawkinsi* (Mansfield) of Trinidad, which is more elongate, smaller, and more fragile, but retains the thickened varices, weak ribbing, and general outline of the former.

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## PLATE 5

Figures

1. *Typhis* (*Talityphis*) sp. (× 3) ..... 160
   USNM 646221; height 17.7 mm, diameter 9.2 mm.
   Locality: TU 958. Gatun Fm., middle Miocene.
2. *Typhis* (*Talityphis*) *pterinus* Gardner (× 2) ..... 163
   USNM 371860 (holotype); height 18.8 mm, diameter 12.5 mm.
   Locality: Shell Bluff, Shoal River, Walton County, Florida. Shoal River Fm., middle Miocene.

3-4. *Typhis* (*Talityphis*) *carmenae* Gertman, n. sp. ..... 166
   3. (× 2) USNM 646222 (holotype); height 20.6 mm, diameter 12.6 mm.
      Locality: TU 638. Agueguexquite Fm., upper Miocene.
   4. (× 1½) IGM 2186 (paratype); height 27.3 mm, diameter 18.5 mm.
      Locality: Paso Real, Tuxtepec, Oaxaca, Mexico. Agueguexquite Fm., upper Miocene.

5-6. *Typhis* (*Talityphis*) *expansus* Sowerby (× 2) ..... 167
   5. USNM 646223; height 25.7 mm, diameter 18.0 mm.
      Locality: TU 954. Moín Fm., Pleistocene.
   6. USNM 696659; height 21.5 mm, diameter 14.0 mm.
      Locality: *Oregon* Station 2331, Surinam Coast. Recent.

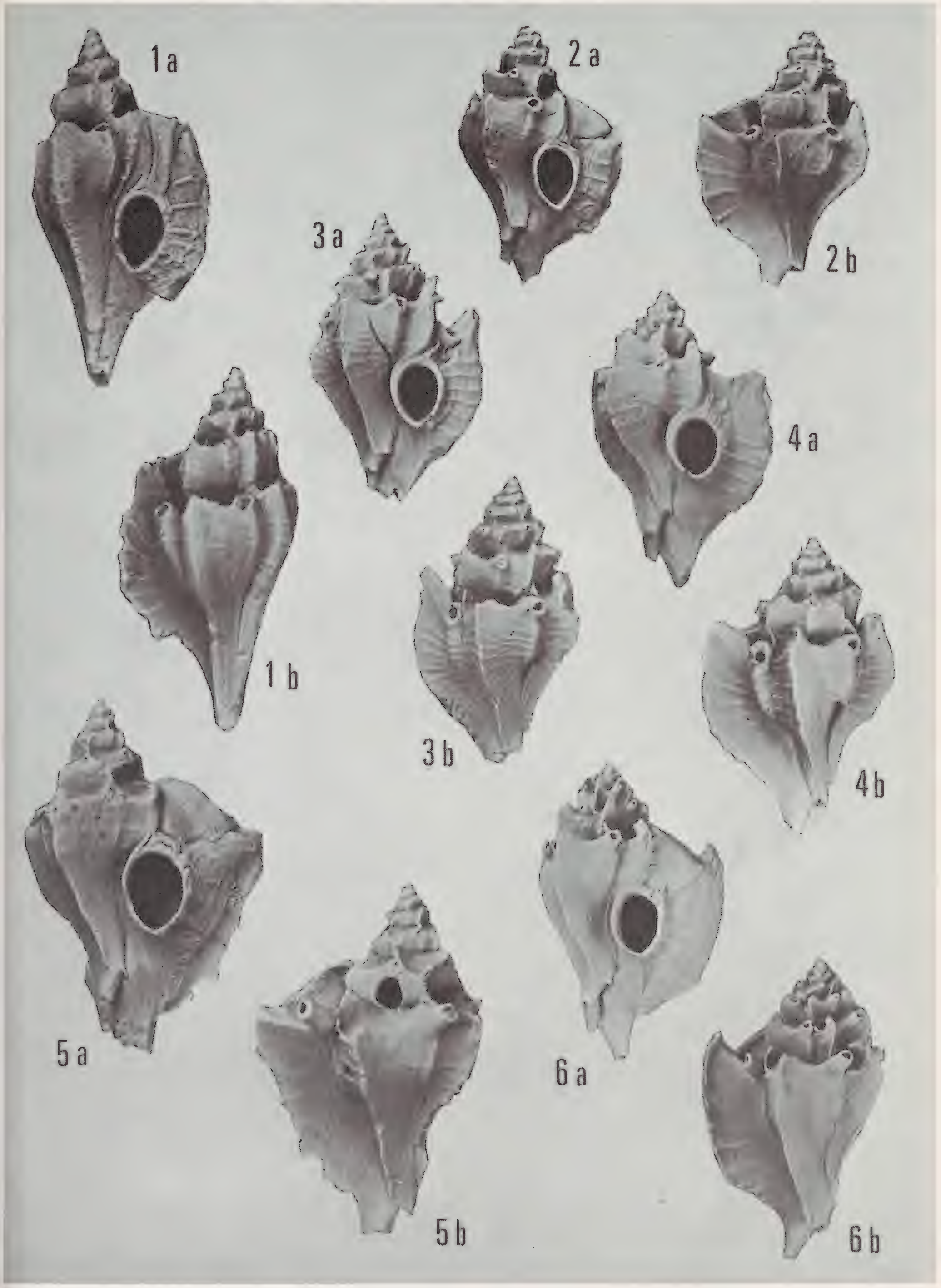


PLATE 5

### SIPHONOCHELUS (LAEVITYPHIS) SCHENCKI (Keen and Campbell)

Plate 6, figs. 4a, b

*Laevityphis* (*Laevityphis*) *schencki* KEEN and CAMPBELL, 1964, Veliger, v. 7, no. 1, p. 53, pl. 9, figs. 16, 20.

"Shell of moderate size, solid, biconic; protoconch partially missing and early spire whorls somewhat worn; shoulder sloping; periphery acute and contracted; body whorl markedly convex contracting sharply at base; varices four per whorl, narrow oblique folds crossing shoulder and joining previous whorl; top of each varix mounted by a long narrow radially directed spine located low on shoulder, bent anteriorly; tubes slightly closer to succeeding varix, joined to it by a buttress, angled slightly forward or ventrally, inclined moderately toward apex; aperture oval; anterior canal broad, reinforced by earlier canals, elongate, closed, inclined obliquely to the left." (Keen and Campbell, 1964)

Holotype: Stanford Univ. Paleo. Type Coll. no. 9723; height 19.0 mm, maximum diameter 15.2 mm.

Type locality: Puerto Colombia (Lat. 11° 03′ N, Long. 75° 00′ W), Dept. Atlantico, Colombia.

*Occurrence*: Las Perdices Shale, Colombia; early lower Miocene (Aquitanian).

*Figured specimen*: SUPTC 9723 (holotype).

*Discussion*: In the original description *S.* (*Laevityphis*) *schencki* was compared with *S. sawkinsi* from the lower and middle Miocene of Trinidad. It differs from that species in having a more sloping shoulder and in having the varical spines located lower on the periphery than the tubes. The holotype, and only known specimen, came from beds that are considered by Keen and Campbell to be Aquitanian in age and thus is slightly older than any of the other Caribbean species.

In their discussion the authors noted that the type specimen was originally labelled in the Stanford University collection as "*Typhis siphonifera* Dall." This was in all probability an error for "*Typhis*" *linguiferus* Dall, a species similar to *S. schencki*. *Typhis* (*Typhina*) *siphonifer* Dall is a completely different form and cannot be compared to *S. schencki* other than at the subfamily level. The error was introduced by Anderson (1929, p. 138) who figured a specimen of *S.* (*L.*) *costaricensis* (Olsson), from Colombia, as "*Typhis siphonifera* Dall." *S. costaricensis* differs from *S. schencki* in having a less sloping shoulder and in having the spines directed vertically rather than outward. *S. schencki* is presumed to be ancestral to *S. costaricensis* but not to *S. sawkinsi*.

### SIPHONOCHELUS (LAEVITYPHIS) LINGUIFERUS* (Dall)

Plate 6, figs. 5a, b

*Typhis linguiferus* DALL, 1890, Wagner Free Inst. Sci., Trans., v. 3, pt. 1, p. 152, pl. 12, fig. 7.

[?] *Typhis linguiferus* Dall. BROWN and PILSBRY, 1917, Acad. Nat. Sci. Phila., Proc., v. 69, p. 34 (probably = *S. costaricensis*).

Not *Typhis linguiferus* Dall. MAURY, 1925, Bulls. Amer. Paleontology, v. 10, no. 42, p. 214, pl. 36, figs. 4, 5 (= *Typhis* [*Siphonochelus*] *sawkinsi* Mansfield).

*Laevityphis* (*Laevityphis*) *linguiferus* (Dall). KEEN, 1944, Jour. Paleontology, v. 18, no. 1, p. 59, 65.

*Typhis linguiferus* Dall. GARDNER, 1947, U. S. Geol. Surv. Prof. Paper 142-H, p. 527, pl. 53, fig. 17.

"Shell with two laxly coiled, polished, peripherally-keeled nuclear whorls and six subsequent whorls; surface polished; transverse sculpture of (on each whorl four) strong, thick, rounded varices, which gradually increase from in front backward, each being largest at the shoulder, where it is produced axially into a linguiform, rather pointed spine, between which and the suture the varix is depressed, then rises against the preceding whorl, where it is expanded and appressed; the spines are bent inward and to some extent backward, the varix is strongly marked by the incremental lines and is linked to the tube, which precedes it by a little elevated ridge, but there is no similar connection with the succeeding tube; the ends of these spines are generally broken and they then appear hollow for a short distance, but the spines are not pervious and have no connection with the interior of the shell; the tubes are moderately large and, instead of conforming to the curves of the varices, they curve upward, outward, a little backward and a little downward at last, though often broken; from the base of each tube a narrow ridge extends forward in harmony with the incremental lines, and behind this ridge is perceptible the mark of an old resting stage; suture appressed and undulated by the sculpture; between the suture and the shoulder the whorl is somewhat excavated; other spiral sculpture only of a few irregular lines near the periphery, which give the surface a malleated appearance, but are not elevated enough to be termed threads or form con-

* This name should more correctly be spelled *linguifer*, however, the ICZN *Code* Art. 32(a)ii states that "incorrect latinization" does not constitute an "inadvertent error" and does not require emendation.

tinuous ridges; the roundness of the varices is not interrupted by them; as there are four varices to a whorl, there are usually three old canals discernible beside the one in use; there is no umbilical chink; the canal is wholly closed, slender and attenuated; the aperture small, subovate and simple with an elevated rim." (Dall, 1890)

*Description*: Shell small, elongate, with a polished surface; protoconch of one and one-half whorls, smooth, flattened, having a keel around the middle that develops into the edge of the shoulder; six post-nuclear whorls; four convex, smooth varices per whorl; a spine at the top of each varix pointing apically, axially and abaperturally; ends of the spines usually broken off and appearing hollow like the tubes, but the openings are smaller, and do not connect with the inside of the shell; outer lip smooth, of constant width; interapertural area of only one part; aperture ovate, surrounded by a raised rim; tubes midway between varices, pointing apically, abaxially, and abaperturally; shell unornamented, axial growth lines visible only under high magnification; shoulder slightly depressed; suture distinct; anterior canal closed, narrow, pointing to the right and slightly abaperturally.

Holotype: USNM 112183; height 15.0 mm, maximum diameter 7.2 mm.

Type locality: USGS 2212, Ten Mile Creek near the Chipola River, Calhoun County, Florida. (? = TU 546).

*Occurrence*: Chipola Formation and Oak Grove Sand, Florida; late lower Miocene.

*Figured specimen*: USNM 646224; height 14.0 mm, diameter 7.8 mm; locality: TU 456. Other occurrences: TU locality nos. 70, 91, 196, 457, 546, 554, 655, 708, 709, 710, 786, 787, 810, 817, 830, 831, 949, 951, 998.

*Discussion*: *S.* (*Laevityphis*) *linguiferus* appears to be descended from *S. curvirostratus* (Conrad, 1848), which it resembles except for the placement of the tubes, smaller size, slightly greater elongation, and more pronounced spine at the apical end of the varix in the Miocene form. *S. linguiferus* also resembles *S. sawkinsi* (Mansfield, 1925), but has less pronounced growth lines, long spines at the top of the varices, and lacks a high partition connecting the varix with the corresponding varix of the preceding whorl.

Pilsbry and Brown reported "*Typhis linguiferus*" from the middle Miocene (Gatun equivalents) of Cartagena, Colombia. The writer questions this identification as *S. linguiferus* is known otherwise only from the Chipola Formation. The description given by Pilsbry and Brown is sketchy, and is not accompanied by a figure, but their specimen is probably *S. costaricensis* (Olsson, 1922).

*S. linguiferus* is known only from the Chipola Formation and the correlative Oak Grove Sand (late lower Miocene, northwestern Florida), but is represented in the Tulane University collections by more than 500 specimens from 20 localities. It is the most abundant *Laevityphis* in the collections, and second in number only to *Typhis* (*Rugotyphis*) *floridanus* Dall (Pliocene, Florida) among the Typhinae.

### Siphonochelus (Laevityphis) sawkinsi (Mansfield)

Plate 7, figs. 1a, b

*Typhis linguiferus* Dall. Maury, 1925, Bulls. Amer. Paleontology, v. 10, no. 42, p. 214, pl. 47, figs. 4, 5 (*not* of Dall).

*Typhis sawkinsi* Mansfield, 1925, U. S. Natl. Mus., Proc., v. 66, Art. 22, p. 48, pl. 2, fig. 11.

*Laevityphis* (*Laevityphis*) *sawkinsi* Mansfield. Keen, 1944, Jour. Paleontology, v. 18, no. 1, p. 59, 67.

*Typhis* (*Laevityphis*) *sawkinsi* Mansfield. Jung, 1965, Bulls. Amer. Paleontology, v. 49, no. 223, p. 525, pl. 70, figs. 7, 8.

"Shell small, solid, fusiform, strongly axially sculptured, with five remaining whorls, tip broken off. Early whorls carinated, later strongly shouldered below the suture. Axial sculpture of (four on the penultimate whorl and five including the strong lip varix on the body whorl) strong varices alternating with weaker axials bearing at their summits moderately strong, protractive tubes. The varices are very strong on the three anterior whorls, offset to the left at the suture and overlap the preceding whorl, terminating at the base of the intervarical tube and lying between the varix and the rib. Between the varices the deep recessed suture is revealed. Each varix bears on its right margin and directly over the suture a short tube. The intervarical ribs extend on the spire whorls from the shoulder to the following suture, and on the last whorl to the base. A few minute axial growth lines overrun the surface. Aperture elongate-ovate, bordered by a raised rim. Anterior canal curved to the right and on the left side strengthened by three anterior curving varices." (Mansfield, 1925)

*Description*: Shell small, slightly elongate; four strong, smooth varices per whorl; outer lip narrow, of constant width, a large partition above the aperture connecting the varix to that of the preceding whorl; no spine at the apical end of the varix; interapertural area of one part; aperture small, ovate, surrounded by a raised rim; tubes closer to succeeding than preceding varices; shoulder slightly depressed,

crossed by remnants of former partitions; suture distinct; anterior canal closed, narrow, pointing to the right but not abaperturally.

Holotype: USNM 352673; height 14.6 mm, maximum diameter 7.6 mm.

Type locality: Guaico-Tamana Road, 2 chains east of mile 13 from the junction with Eastern Main Road, Trinidad.

*Occurrence*: Brasso and Moruga Formations, Trinidad; unnamed formation, Paraguaná Peninsula, Venezuela; middle Miocene.

*Figured specimen*: USNM 352673 (holotype).

*Discussion*: Maury (1925, p. 214) reported three specimens of Trinidad Typhinae that she thought might be the same as *S. linguiferus* (Dall) from the Chipola Formation of northwestern Florida. Shortly thereafter Mansfield named *"Typhis" sawkinsi* from the same locality. He compared his species with *S. gabbi* (Brown and Pilsbry) from the Gatun Formation of Panamá, but observed that the Trinidad species lacked the wrinkled and pitted sculpture of *S. gabbi*. The writer, among others, refers Maury's specimens to *S. sawkinsi*, as the partition above the aperture crosses the shoulder on the Trinidad specimens unlike that of *S. linguiferus*.

Keen and Campbell (1964, p. 54) suggested that *S. schencki* was probably the precursor of *S. sawkinsi* but the writer disagrees. He believes that *S. sawkinsi* was derived from *S. curvirostratus* (Conrad), Oligocene, Mississippi, which has a depressed shoulder and rounded, thickened varices (as does *S. sawkinsi*) and not from the dissimilar form, *S. schencki* (Keen and Campbell).

*S. sawkinsi* is known from the Brasso and Moruga Formations, middle Miocene of Trinidad, and from the late middle Miocene of the Paraguaná Peninsula, Venezuela (Jung, 1965, p. 525). Maury (1925) reported this species from the Mechapoorie Formation, lower or middle Miocene, Trinidad, but Mansfield (1925, p. 4) and others have referred it to the Navarro River Member of the Brasso Formation.

### Siphonochelus (Laevityphis) costaricensis (Olsson)

Plate 7, figs. 2a, b

*Typhis linguliferus* [*sic*] *costaricensis* Olsson, 1922, Bulls. Amer. Paleontology, v. 9, no. 39, p. 132, pl. 10, figs. 22, 29.

*Typhis siphonifera* Dall. Anderson, 1929, California Acad. Sci., Proc., (Ser. 4) v. 18, no. 4, p. 138, pl. 9, fig. 8 (*not* of Dall).

Not *Typhis costaricensis* Olsson, 1942, Bulls. Amer. Paleontology, v. 27, no. 106, p. 228, pl. 25, figs. 5, 8 (= *Typhis* (*Talityphis*) *olssoni* Keen, 1943, new name).

*Typhis linguliferus* [*sic*] *costaricensis* Olsson. Barrios M., 1960, Bol. Geol., Serv. Geol. Nacl. Colombia, v. 6, p. 279, pl. 9, fig. 9.

"This is a smaller and more delicate species than *T. gabbi* Brown and Pilsbry from the Canal Zone. They agree with the Chipolan *linguliferus* [*sic*] Dall in their general form but differ in their uniformly smaller size and in nearly lacking the spine-like process on the shoulder of the primary varices. It is fairly abundant in the Gatun beds of the Banana River." (Olsson, 1922)

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## Plate 6

Figures Page

1. *Siphonochelus* (*Siphonochelus*) *cercadicus* (Maury) (× 6) ..... 168
   Cornell Paleo. Lab. 36813 (holotype); height 6.6 mm, diameter 3.9 mm.
   Locality: Bluff 1, Cercado de Mao, Dominican Republic. Gurabo Fm., middle Miocene.
2. *Siphonochelus* (*Laevityphis*) *gracilis* (Conrad) (× 3) ..... 171
   ANSP 13755 (lectotype); height 16.8 mm, diameter 8.1 mm.
   Locality: Claiborne Bluff, Alabama. Gosport Sand, middle Eocene.
3. *Siphonochelus* (*Laevityphis*) *curvirostratus* (Conrad) (× 2) ..... 172
   ANSP 13484a (lectoparatype); height 19.8 mm, diameter 12.2 mm.
   Locality: Vicksburg, Mississippi. (?) Byram Marl, middle Oligocene.
4. *Siphonochelus* (*Laevityphis*) *schencki* (Keen and Campbell) (× 3) ..... 174
   SUPTC 9723 (holotype); height 19.0 mm, diameter 15.2 mm.
   Locality: Puerto Colombia, Dept. Atlantico, Colombia. Las Perdices Shale, lower Miocene.
5. *Siphonochelus* (*Laevityphis*) *linguiferus* (Dall) (× 3) ..... 174
   USNM 646224; height 14.0 mm, diameter 7.8 mm.
   Locality: TU 456. Chipola Fm., lower Miocene.

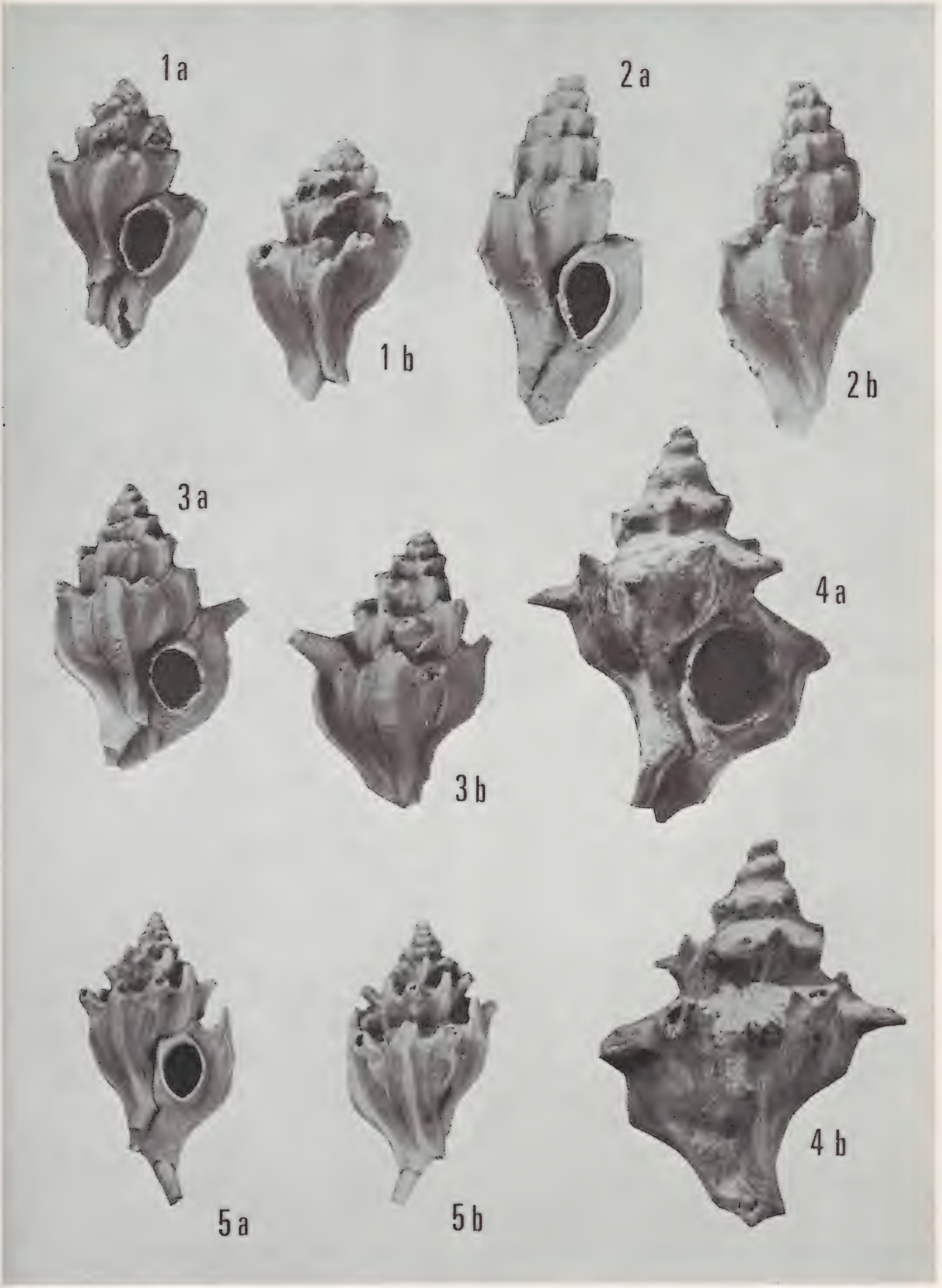


PLATE 6

*Description*: Shell small, elongate; protoconch smooth, rounded, of one and one-half whorls; five post-nuclear whorls; four smooth convex varices per whorl; outer lip smooth, narrow, of constant width; a partition connecting the varix with the corresponding varix of the preceding whorl; interapertural area of only one part; aperture rounded, surrounded by a raised rim; tubes closer to succeeding than preceding varices, pointing abaxially and apically; surface of the shell smooth; shoulder slightly depressed, crossed by remnants of partitions; suture distinct; anterior canal closed, elongate, narrow, pointing to the right and abaperturally.

Lectotype: PRI 21060; height 12.7 mm, maximum diameter 7.3 mm (here designated).

Type locality: Hill 1A, Banano River, Costa Rica.

*Occurrence*: Gatun Formation, Costa Rica; Tuberá Group, Colombia; middle Miocene.

*Figured specimen*: PRI 21060 (lectotype).

*Discussion*: *S.* (*Laevityphis*) *costaricensis* is closely related to *S. sawkinsi* (Mansfield, 1925). The two forms are similar in having rounded, convex varices, and large partitions crossing the shoulder above the aperture. The two differ in that *S. costaricensis* is more elongate, and has thinner varices. This species differs from *S. linguiferus* (Dall, 1890) by its more elongate shape, partitions above the aperture, and shorter spines at the apical end of the varices. The shoulder is not as depressed in this form as it is in both *S. sawkinsi* and *S. linguiferus*.

This species was figured by Anderson (1929, pl. 9, fig. 8), from the Miocene of Colombia, as "*Typhis siphonifera* Dall," an apparent error for *S. linguiferus*. This error has been copied by subsequent workers with resulting confusion as the two have little in common.

Olsson named this form as a subspecies of *S. linguiferus* but it is no more closely related to *S. linguiferus* than to any other of the Caribbean species of *Laevityphis* and so the subspecific rank is removed. There being two specimens in the type lot, the first one figured by Olsson (1922, pl. 10, fig. 22) is selected as lectotype. It is the specimen now given the Paleontological Research Institution number 21060, the other figured specimen is PRI 21061.

It should also be noted that, although the usual spelling of the type locality of this species has been "Banana River," on the topographic map of the area prepared by the Instituto Geografico de Costa Rica it is spelled *Banano* (Rio Banano sheet, no. HOJA 3545 1).

### Siphonochelus (Laevityphis) bullisi Gertman, n. sp.

Plate 7, figs. 3a, b

*Description*: Shell large; smooth, bulbous protoconch of one and one-half whorls; six post-nuclear whorls; four smooth thickened varices per whorl, each with a spine at the apical end pointing apically and abaxially; outer lip smooth, of constant width, with a strong angle at the base of the body whorl; interapertural area of only one part; aperture ovate, surrounded by a raised rim; tubes midway between the varices, pointing abaxially and abaperturally; area under the tubes raised, forming axial ribs between the varices, shell surface smooth and polished; shoulder raised, suture appressed and indistinct; anterior canal closed, long, narrow, curving to the right and abaperturally.

Holotype: USNM 696660; height 26.7 mm, maximum diameter 13.0 mm.

Type locality: *Oregon* Station 5727, Gulf of Darién, Panamá, 43 fms.

*Occurrence*: Moín Formation, Costa Rica; Pleistocene. Caribbean Sea, Recent.

*Figured specimen*: USNM 696660 (holotype). Other occurrences: TU locality no. 953.

*Discussion*: This new species, the first Recent *Laevityphis* known from the New World, is represented by over 20 specimens from the type locality as well as fragments from the Pleistocene Moín Formation of Costa Rica. As the oldest group of Typhinae it is not too surprising that the Recent distribution is disjunct. The line was once much more widespread with representatives in all parts of the tropics. *S. bullisi* is easily distinguished from all other species of *Laevityphis* (except perhaps *L. schencki*) by the strong angulation at the base of the body whorl.

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### Subgenus Pilsbrytyphis Woodring, 1959

*Pilsbrytyphis* Woodring, 1959, U. S. Geol. Surv. Prof. Paper 306-B, p. 220.
Type species: *Typhis gabbi* Brown and Pilsbry, 1911, by original designation.

> "Five [four] varices to a whorl. Tubes midway between varices, slightly bent backwards. All except earliest whorls bearing irregular axially wrinkled and pitted sculpture. Aperture small. Siphonal canal short, moderately bent." (Woodring, 1959)

*Discussion*: The few species of *Pilsbrytyphis* are undoubtedly derived from a *Laevityphis* ancestor as the morphology of the shell is almost identical, being distinguished

only by the very non-*Laevityphis* nature of the wrinkled shell surface. The latter was characterized most aptly by Woodring as "peanut-shell" sculpture. In contrast, the shell surface of *Laevityphis* and of all the other subgenera of *Siphonochelus* is completely smooth and highly polished.

The members of *Pilsbrytyphis* are confined to the middle Miocene beds of Panamá and it is evident that this bizarre development was a biological failure. This type of the subgenus, *S. gabbi*, occurs in the middle Gatun Formation of the Panamá Canal Zone. In addition, two new species are described herein: *S.* (*Pilsbrytyphis*) *woodringi*, from the upper Gatun Formation of the Canal Zone; and *S. darienensis*, from the middle Miocene of the Darién region of eastern Panamá.

### Siphonochelus (Pilsbrytyphis) gabbi (Brown and Pilsbry)

Plate 7, figs. 4a, b

*Typhis gabbi* Brown and Pilsbry, 1911, Acad. Nat. Sci. Phila., Proc., v. 63, p. 354, pl. 26, fig. 6.

*Typhis* (*Typhina*) *gabbi* Brown and Pilsbry. Keen, 1944, Jour. Paleontology, v. 18, no. 1, p. 55, 65.

*Typhis* (*Pilsbrytyphis*) *gabbi* Brown and Pilsbry. Woodring, 1959, U. S. Geol. Surv. Prof. Paper 306-B, p. 220, in part only, *not* pl. 32, figs. 2, 3, 5, 7.

> "The shell is fusiform, strong, the last whorl having a peculiar sculpture, the surface shrivelled, wrinkled and pitted. The embryo, of nearly two very convex smooth whorls, forms a short style or pillar. Then the diameter enlarges, and a shoulder-angle appears on the latter part of the third whorl. In the middle of the fourth whorl varices and intervariceal tubes appear on the very prominent shoulder, these structures gradually increasing in size to the last whorl, which bears four varices. These are strong and heavy, rounded, somewhat recurved above the shoulder, where there is a deep pit behind each varix. The tubes are short, midway between the varices, and placed upon low short folds. The aperture is very small, oval, with a raised rim. Anterior canal closed, bent to the right, having three projecting angles on the left side." (Brown and Pilsbry, 1911)

*Description*: Shell small, stout; five postnuclear whorls; four convex varices per whorl; outer lip of constant width, with only vestigial spines at apical end of varix; a large partition riding up upon the preceding whorl to form a strong buttress-like structure with a deep concavity behind it; shell covered with a semireticulate pattern trending spirally around the shell; interapertural area in two parts: first, the area under the tube, second, the new varix, the two areas being distinguished by an offset in the pattern of the ornamentation; aperture small, ovate-rounded, surrounded by a raised rim; tubes midway between varices, pointing abaxially and apically from the shoulder; shoulder raised; suture distinct; anterior canal closed, narrow, bending to the right and abaperturally.

Holotype: ANSP 1722; height 13.3 mm, maximum diameter 7.6 mm.

Type locality: Gatun Locks excavation, Canal Zone.

*Occurrence*: Gatun Formation, Canal Zone; middle Miocene.

*Figured specimen*: ANSP 1722 (holotype).

*Discussion*: The specimens that Woodring (1959, p. 220, pl. 32, figs. 2, 3, 5, 7) discussed and figured as "*Typhis*" (*Pilsbrytyphis*) *gabbi* Brown and Pilsbry are not this species but a new one described below as (*P.*) *woodringi*. So far as is known there are but the two original specimens of true *S. gabbi*, which came from the middle part of the Gatun Formation at the Gatun Locks excavation. The specimens referred to *S. woodringi* all come from the upper part of the Gatun Formation in the vicinity of Mount Hope, Canal Zone.

Woodring (*ibid.* p. 220) described *S. gabbi* as having five varices per whorl but the writer believes that he included the last varix of the preceding whorl in his count, for the type has but four varices per whorl. He added that by Keen's key (1944, p. 52) it is a member of the subgenus *Typhina*, which has four varices per whorl, with the tubes midway between the varices. On all other grounds, however, the form is more akin to *Laevityphis* except for the unusual surface sculpture, which caused Woodring to erect the new subgenus *Pilsbrytyphis* for the group. Morphologically *S.* (*Pilsbrytyphis*) *gabbi* is very close to *S.* (*Laevityphis*) *sawkinsi* (Mansfield) from the middle Miocene of Trinidad and Venezuela and probably represents a mutation of this stock.

### Siphonochelus (Pilsbrytyphis) darienensis Gertman, n. sp.

Plate 7, figs. 5a, b

*Description*: Shell large, massive; nucleus of one and one-half smooth whorls; six postnuclear whorls; four thickened, sculptured varices per whorl with a high, hollow spine at the top of each varix, directed apically; these spines usually broken off to mimic tubes; spire high; tubes closer to succeeding than pre-

ceding varices, pointing abaxially, apically, and aperturally; suture appressed; varices joined to preceding whorl by a small partition; entire shell surface covered with axially directed, longitudinal wrinkles that follow the growth pattern of the shell; aperture ovate, surrounded by a raised rim; anterior canal closed, narrow, curving to the right and abaperturally.

Holotype: USNM 646114; height 22.3 mm, maximum diameter 12.6 mm.

Type locality: USGS 8477, Rio Tuira, Darién, Panamá.

*Occurrence*: "Tuira Formation," Darién, Panamá; middle Miocene.

*Figured specimen*: USNM 646114 (holotype).

*Discussion*: Woodring (1959, p. 220), in his discussion of *"Typhis" gabbi,* mentioned that there was another undescribed species of *Pilsbrytyphis* from the Darién region of Panamá. It is the species here described. Although related to *S. gabbi* it is nearer to the other species of *Pilsbrytyphis* described below, which is the *"T. gabbi"* of Woodring, not of Brown and Pilsbry. From that species it differs in its larger size, weaker sculpture, and in having the spines and tubes more well developed at an earlier stage, giving the spire of the shell an especially cororated appearance.

This new species is not rare, in the type lot there are 11 specimens. They were collected by A. A. Olsson on the Rio Turia near Limones, from beds which are equivalent to the Gatun Formation of the Canal Zone. According to the *Lexique Stratigraphique International* (v. 5, Fasc. 2a, Amérique Centrale, p. 317 & 349) the name "Turia Formation" has been proposed for these strata but has not been properly defined. This formation is said to underlie the Pucro Sandstone, which carries a fauna very similar to that of the Gatun near Mount Hope, Canal Zone, from whence comes the type specimen of *S. (Pilsbrytyphis) woodringi* Gertman, n. sp., and it is concluded that *S. darienensis* is slightly older than *S. woodringi.*

### Siphonochelus (Pilsbrytyphis) woodringi Gertman, n. sp.

Plate 7, figs. 6a, b

*Typhis (Pilsbrytyphis) gabbi* Brown and Pilsbry. Woodring, 1959, U. S. Geol. Surv. Prof. Paper 306-B, p. 220 (in part *not* of Brown and Pilsbry), pl. 32, figs. 2, 3, 5, 7.

*Description*: Shell medium-sized; nucleus of one and one-half smooth whorls, blunt tipped; six post-nuclear whorls; four thickened varices per whorl with a small recurved spine at the top of each varix pointing abaperturally; spire high; tubes closer to succeeding than preceding varices, pointing abaxially, apically, and abaperturally; shoulder appressed at varices, depressed between; suture distinct; varices joined to preceding whorl by a small partition; entire shell covered with axially-oriented wrinkled sculpture; aperture oval, surrounded by a raised rim; anterior canal closed, narrow, curving to the right and abaperturally.

Holotype: USNM 562627; height 20.3 mm, maximum diameter 10.8 mm.

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## Plate 7

Figures Page

1. *Siphonochelus (Laevityphis) sawkinsi* (Mansfield) (× 3) ---- 175
USNM 352673 (holotype); height 14.6 mm, diameter 7.6 mm.
Locality: Trinidad. Brasso Fm., middle Miocene.
2. *Siphonochelus (Laevityphis) costaricensis* (Olsson) (× 3) ---- 176
PRI 21060 (lectotype); height 12.7 mm, diameter 7.3 mm.
Locality: Banano River, Costa Rica. Gatun Fm., middle Miocene.
3. *Siphonochelus (Laevityphis) bullisi* Gertman, n. sp. (× 2) ---- 178
USNM 696660 (holotype); height 26.7 mm, diameter 13.0 mm.
Locality: *Oregon* Station 5727, Gulf of Darién, Panamá. Recent.
4. *Siphonochelus (Pilsbrytyphis) gabbi* (Brown and Pilsbry) (× 3) ---- 179
ANSP 1722 (holotype); height 13.3 mm, diameter 7.6 mm.
Locality: Gatun Locks, Canal Zone. Gatun Fm., middle Miocene.
5. *Siphonochelus (Pilsbrytyphis) darienensis* (Gertman, n. sp. (× 2) ---- 179
USNM 646114; height 22.3 mm, diameter 12.6 mm.
Locality: Rio Tuira, Darién, Panamá. "Tuira Fm.," middle Miocene.
6. *Siphonochelus (Pilsbrytyphis) woodringi* Gertman, n. sp. (× 2) ---- 180
USNM 562627 (holotype) height 20.3 mm, diameter 10.8 mm.
Locality: Near Mt. Hope, Canal Zone. Gatun Fm., middle Miocene.

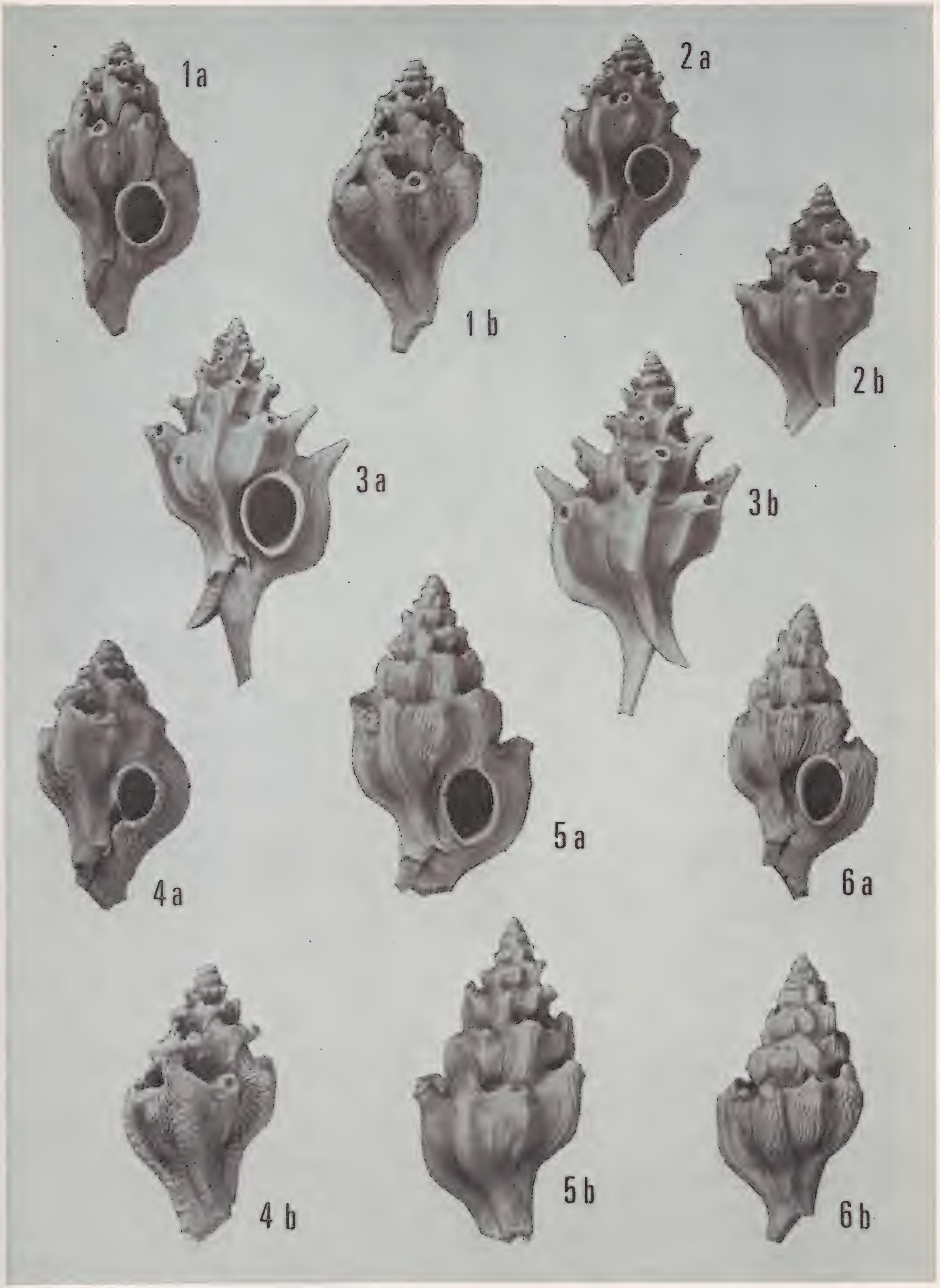


PLATE 7

Type locality: USGS 8410, cuts on west side of East Diversion, Mount Hope, Canal Zone (Woodring locality 175).

*Occurrence*: Gatun Formation, Canal Zone; middle Miocene.

*Figured specimen*: USNM 562627 (holotype) (specimen figured by Woodring, 1959, pl. 32, figs. 5, 7).

*Discussion*: As noted above, the specimens cited by Woodring (1959, p. 220, pl. 32, figs. 2, 3, 5, 7) as *"Typhis" gabbi* Brown and Pilsbry are not that species. The form, here named in honor of Dr. Wendell P. Woodring, differs from the true *S. gabbi* in having the characteristic "peanut-shell" sculpture oriented axially instead of spirally as in *S. gabbi*, and in lacking the pronounced buttress-like partition of that species, having instead small, recurved spines at the top of the varices.

This species is common in the vicinity of the type locality, there being 18 specimens in the USNM collections from near Mount Hope, Canal Zone. Stratigraphically it is the last of the three known species of *Pilsbrytyphis*, occurring in the upper part of the Gatun Formation.

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## Genus PTEROTYPHIS Jousseaume, 1880
## Subgenus PTEROTYPHIS s.s.

*Pterotyphis* JOUSSEAUME, 1880, Le Naturaliste, Année 2, no. 42, p. 336 (originally spelled as *Perotyphis*, but corrected in errata, Le Naturaliste, Année 3, no. 43, p. 367, 1881); 1882, Rev. Mag. Zool., (Ser. 3) v. 7, p. 338.
Type species: *Typhis pinnatus* Broderip, 1833, by original designation.

*Trigonotyphis* JOUSSEAUME, 1882, Rev. Mag. Zool., (Ser. 3) v. 7, p. 339.
Type species: *Typhis fimbriatus* A. Adams, 1854, by original designation.

> "Coquille ovale à spire élevée, conique, tours avec des varices saillantes et foliaées et des côtes circulaires; ouverture ovale; canal très court." (Jousseaume, 1882)

Shell with three varices and tubes per whorl; tubes nearer to succeeding than to preceding varices, pointing abaperturally and abaxially; siphonal canal not closed but open by a narrow slit; strong sculpture present.

*Discussion*: *Pterotyphis* s.s. is a small, but distinctive, group. It is unique among the Typhinae in having the siphonal canal not sealed over. There are but three known species, one in the Gulf of California, *P. fimbriatus* (A. Adams, 1854); one in the Caribbean, *P. pinnatus* (Broderip, 1833), of which *P. fordi* (Pilsbry, 1943) is a synonym; and one fossil species, described herein, from the lower Miocene Chipola Formation of Florida.

From Jousseaume's original description of *Pterotyphis* it is not at all certain that he really knew what he was describing. His description of *Trigonotyphis*, which appeared on the following page, is a much more adequate description of the form, mentioning the resemblance to *Murex triqueter* and the presence of the open canal. The name is indicative of the presence of only three varices. Nevertheless, the selection of *P. pinnatus* as the type of *Pterotyphis*, was sufficient to describe the genus and, as it has two years priority, there is no question of which name is preferable.

DuShane (1969, p. 343) has recently described a new genus of Typhinae, to which the name *Cinclidotyphis* was given. Although compared by the author to *Siphonochelus*, it is obvious that this new form is most closely related to *Pterotyphis*. The only difference between this new West American species, *C. myrae*, the type of the genus, and *P. pinnatus*, type of *Pterotyphis*, is the presence of the more normal four varices and tubes per whorl in the new species. Otherwise, the nature of the cancellate ornamentation, the open siphonal canal, the formation of the tubes, all are virtually identical in the two forms. Because the presence of only three varices has been considered as a generic character in *Pterotyphis* the writer does not place the two taxa in synonymy, but it is strongly felt that the two groups are so closely related that a subgeneric separation is the maximum distinction possible.

### PTEROTYPHIS (PTEROTYPHIS) CALHOUNENSIS Gertman, n. sp.
### Plate 8, figs. 1a, b

*Description*: Shell small, highly ornamented; early whorls unknown; three convex varices per whorl, each crossed by eight or nine strong spiral ribs, the two anterior-most of which are composed of three weaker ribs; axial ribbing only slightly less prominent than spiral, giving the shell a cancellate sculpture; tubes just behind and soldered to, the succeeding varix; aperture ovate, with a sinuous outer margin; outer lip crenulated with about seven ribs; anterior canal open by a narrow slit, turned to the right and abaperturally.

Holotype: USNM 646225; height (incomplete) 8.0 mm, maximum diameter 5.5 mm.

Type locality: TU 547, west bank of Chipola River, about 2000 ft. above the mouth of Four

Mile Creek (SW ¼ Sec. 29, T1N, R9W), Calhoun County, Florida.

*Occurrence*: Chipola Formation, Florida; late lower Miocene.

*Figured specimen*: USNM 646225 (holotype).

*Discussion*: Although the only specimen known of *P. calhounensis* is incomplete, inasmuch as it is the first known fossil of the subgenus, it was deemed by the writer too important to remain unnamed. Only the body whorl is preserved but all of the characters of the species can be ascertained except the total number of whorls.

*P. calhounensis* is similar to *P. pinnatus* but differs in the much coarser nature of the cancellate sculpture of the Chipola shell.

### Pterotyphis (Pterotyphis) pinnatus (Broderip)

Plate 8, figs. 2 a, b

*Typhis pinnatus* Broderip, 1833, Zool. Soc. London, Proc., pt. 2, p. 178.

*Typhis pinnatus* Broderip. G. B. Sowerby, Jr., 1841, Conch. Illus., pl. 200, figs. 10, 11.

*Typhis fordi* Pilsbry, 1943, Nautilus, v. 57, p. 40, pl. 7, fig. 4.

*Pterotyphis* (*Pterotyphis*) *pinnatus* (Broderip). Keen, 1944, Jour. Paleontology, v. 18, no. 1, p. 59, 66.

> "Typhis testa alba, fusiformi, trifariam pinnata, transversim striata, striis frequentibus, interstitiis punctatis; labri limbo crenulato . . . The sides of the canal in the specimen are broken, but the canal does not appear to have been entire close to the aperture, though the sides of it approximate there very nearly." (Broderip, 1833)

*Description*: Shell small, elongate; protoconch rounded, smooth, of one and one-half whorls; six post-nuclear whorls; three convex varices per whorl, each crossed by 12 crenulations; outer lip wide, of one part, flanged and crossed by 12 ribs, the anterior ones divided into primary ribs flanked on either side by one weaker rib; shell ornamented by strong spiral sculpture and sharp varices; axial growth lines giving a cancellate appearance to the surface of the shell; tubes nearer to succeeding than preceding varices, attached but not soldered to the varix; tubes made of two parts: an inner circular tube, surrounded by a striated flange that appears to be wrapped around the tube with a distinct suture line on the adapertural side of the tube; tubes pointing abaxially, abaperturally, and apically; aperture ovate, with a sinuous outer margin; anterior canal open with a narrow slit, curving to the right and abaperturally.

Holotype: Not found; height 6/8 inch, diameter 2/8 inch (*fide* Broderip, 1833).

Type locality: New Providence Island (Nassau), Bahama Islands (here designated).

*Occurrence*: Moín Formation, Costa Rica; Pleistocene. Caribbean Sea and western Atlantic, Recent.

*Figured specimen*: USNM 646226; height 12.3 mm, maximum diameter 6.4 mm; locality; TU 954. Other occurrences: TU locality nos. R-100, R-101.

*Discussion*: *P. pinnatus* (Broderip) was named without locality data but there seems no doubt that the western Atlantic shell subsequently named *Typhis fordi* Pilsbry is this species. As no type locality has ever been designated, New Providence Island, Bahama Islands, the type locality of *P. fordi*, is here selected. This species is evidently not rare in the Bahamas as it has been reported by several collectors from that area. Prior to this paper it has never been reported from the Caribbean but in the Tulane Collections there are two specimens from off northern Panamá dredged by the *Anton Bruun* Cruise 10. In addition, the species also occurs in the Pleistocene Móin Formation of Costa Rica.

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## Subgenus Tripterotyphis Pilsbry and Lowe, 1932

*Tripterotyphis* Pilsbry and Lowe, 1932, Acad. Nat. Sci. Phila., Proc., v. 84, p. 78.
Type species: *Typhis lowei* Pilsbry, 1931, by original designation.

*Nothotyphis* Fleming, 1962, Roy. Soc. New Zealand (Zool.), Trans., v. 2, no. 14, p. 116.
Type species: *Pterynotus* (*Nothotyphis*) *norfolkensis* Fleming, 1962, by original designation.

> "Shell with three broad varices continuous from whorl to whorl, ascending the spire in a slowly revolving spiral. Tubes wholly concrescent with the posterior angles of the varices, where they are terminal." (Pilsbry and Lowe, 1932)

Shell with three varices per whorl; tubes within the varices; shell sculptured.

*Discussion*: Dr. C. A. Fleming, Chief Paleontologist of the New Zealand Geologic Survey, stated (1962, p. 117) his belief that those muricids with varical tubes were to be referred to the Muricinae rather than the Typhinae. He established the subgenus *Nothotyphis*, in the genus *Pterynotus*, for muricids having three varices per whorl with the tubes in the varices. Keen and Campbell (1964, p. 56), in a study of the formation of the varical tubes of *Tripterotyphis* from a growth series, concluded that this development seems to be "closely re-

lated to other Typhinae rather than to the muricine group *Pterynotus* Swainson, 1833." Morphologically *Nothotyphis* is so similar to *Tripterotyphis* that the two taxa must be considered synonymous.

In those forms of Typhinae in which the tubes are developed between the varices their relative position within this interval is variable, and the writer sees no valid reason for excluding from the subfamily those forms in which this variation has reached the stage wherein the tubes are located within the varices. It is to be noted that an intermediate condition is observed in *Siphonochelus* s.s. Here the tubes initially appear as a strongly infolded notch on the back of the varix, which later closes over to form a tube that is situated half within and half behind the varix. Also, in *Tripterotyphis* the anterior canal is closed as it is in the majority of the Typhinae, but none of the Muricinae exhibit this feature.

There is another typhine subgenus, *Semityphis* Martin, 1931, named for an Eocene species from Java, that is superficially similar to *Tripterotyphis*. *Semityphis* also has three varices with the tubes contained within the varices. However, these two forms probably represent parallel evolution for morphologically they appear quite different. *Semityphis* is an almost smooth shell, unlike the cancellate *Tripterotyphis*, and is ornamented only by a strong spiral rib at the periphery, giving the shell a marked biconic outline. The type specimen is a juvenile, measuring only 5.5 mm, and with only three post-nuclear whorls. The siphonal canal is open but this may be due to immaturity or breakage. The tubes are almost flush with the varices much as in the subgenus *Lyrotyphis*. This combined with the smooth shell surface, and the comparable geologic age suggests that *Semityphis* is more nearly related to *Lyrotyphis* than to *Pterotyphis*, in spite of having three varices, and so is herein placed in the genus *Siphonochelus*.

There are eight known species of *Tripterotyphis*, ranging in age from lower Miocene to Recent. *P.* (*Tripterotyphis*) *vokesae*, n. sp., from the late lower Miocene Chipola Formation of northwestern Florida is the oldest reported *Tripterotyphis* in the New World. *P. tripterus* (Grateloup, 1833), is known from the lower Miocene of France, and the middle Miocene of Hungary. *P. wenzelidesi* (Hörnes, 1856) is a synonym of *P. tripterus*.

In the Recent fauna there are two species of *Tripterotyphis* from the New Zealand-Australia area, those being the species referred to *Nothotyphis* by Fleming. There are three species from tropical West America: *P. fayae* Keen and Campbell, 1964, from the Pleistocene and Recent of western Mexico, *P. arcana* DuShane, 1969, also from west Mexico, and *P. lowei* (Pilsbry, 1931), described from the reefs at low tide off the Pacific Coast of Panamá. *P.* (*T.*) *triangularis* (A. Adams, 1856), described without locality data, is now known to be from the Caribbean region. (The name *Murex cancellatus* Sowerby, 1841, is a homonym and is replaced by *P. triangularis*.) This species also occurs in the Pleistocene of southern Florida.

## Pterotyphis (Tripterotyphis) vokesae Gertman, n. sp.

Plate 8, figs. 3a, b

*Description*: Shell small; protoconch smooth, rounded, two and one-half whorls; five post-nuclear whorls; three narrow, convex varices per whorl, each bearing a thin flange which extends from the tube to the distal end of the siphonal canal; nine crenulations on the outer lip and varices; suture distinct at varices, slightly appressed in the interapertural area; tubes within the varices, pointing apically and abaperturally; aperture ovate, pointed anteriorly surrounded by a raised rim with a sinuous outer margin; spiral ornamentation of moderately strong primary ribs; a secondary rib between each pair of primaries, and a tertiary riblet between the primary and secondary ribs; siphonal fasciole bearing remnants of two former canals; anterior canal closed, broad, pointing to the right and abaperturally.

Holotype: USNM 646227; height 13.5 mm, maximum diameter 6.5 mm.

Type locality: TU 546, Ten Mile Creek, about 1½ miles west of the Chipola River (NE ¼ Sec. 12, T1N, R10W), Calhoun County, Florida.

*Occurrence*: Chipola Formation, Florida; late lower Miocene.

*Figured specimen*: USNM 646227 (holotype). Other occurrences: TU locality nos. 951, 998.

*Discussion*: *Pterotyphis* (*Tripterotyphis*) *vokesae* resembles *P.* (*T.*) *tripterus* (Grateloup, 1833) from the Miocene of France and Hungary except for the higher spire, weaker apertural lip, the wider base of the tubes, and the more flattened intervarical

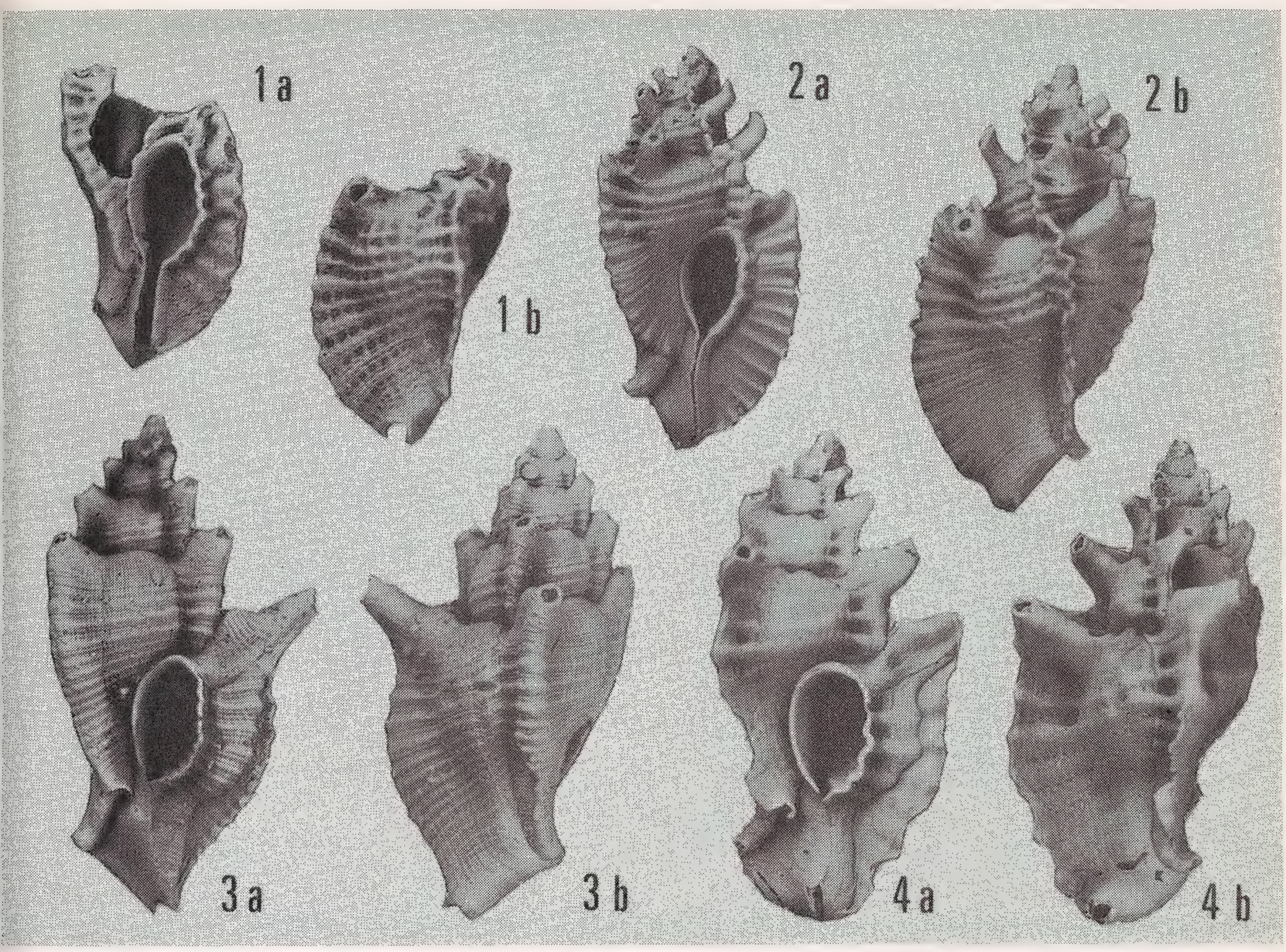


PLATE 8

Figures

1. *Pterotyphis* (*Pterotyphis*) *calhounensis* Gertman, n. sp. (× 4) ..... 182
   USNM 646225 (holotype); height (incomplete) 8.0 mm, diameter 5.5 mm.
   Locality: TU 547. Chipola Fm., lower Miocene.
2. *Pterotyphis* (*Pterotyphis*) *pinnatus* (Broderip) (× 4) ..... 183
   USNM 646226; height 12.3 mm, diameter 6.4 mm.
   Locality: TU 954. Moín Fm., Pleistocene.
3. *Pterotyphis* (*Tripterotyphis*) *vokesae* Gertman, n. sp. (× 4) ..... 184
   USNM 646227 (holotype); height 13.5 mm, diameter 6.5 mm.
   Locality: TU 546. Chipola Fm., lower Miocene.
4. *Pterotyphis* (*Tripterotyphis*) *triangularis* (A. Adams) (× 3) ..... 186
   USNM 646228; height 17.5 mm, diameter 9.9 mm.
   Locality: TU 759. Unnamed post-Caloosahatchee formation, Pleistocene.

area, which causes the shell to appear more angular. The two species are equivalent in age, but geographically widely separated. Both are known from only a few specimens. The holotype of *P. vokesae* is one of four complete specimens in the Tulane University collections, but there are fragments of seven others.

The writer is pleased to dedicate this new species to Dr. Emily H. (Mrs. H. E.) Vokes in appreciation for her constant encouragement and her patience in putting up with his multitudinous questions.

### Pterotyphis (Tripterotyphis) triangularis (A. Adams)

Plate 8, figs. 4a, b

*Murex cancellatus* G. B. Sowerby, Jr., 1841, Zool. Soc. London, Proc., pt. 8, p. 143; 1841, Conch. Illus., pl. 190, fig. 79 (not *Murex cancellatus* Gmelin, 1791).

*Typhis triangularis* A. Adams, 1856, Zool. Soc. London, Proc., pt. 23, p. 124.

*Typhis cancellatus* (Sowerby). Tryon, 1880, Manual of Conchology, v. 2, p. 138, pl. 30, fig. 303.

*Typhis* (*Tripterotyphis*) *cancellatus* Sowerby. Smith, 1939, Cat. Recent species Rock shells, p. 18, pl. 14, fig. 7.

*Pterotyphis* (*Tripterotyphis*) "*cancellatus*" (Sowerby). Keen, 1944, Jour. Paleontology, v. 18, no. 1, p. 61, 63.

*Pterotyphis* (*Tripterotyphis*) *triangularis* (A. Adams). Keen, 1944, Jour. Paleontology, v. 18, no. 1, p. 67.

*Typhis triangularis* Adams. Keen and Campbell, 1964, Veliger, v. 7, no. 1, p. 55.

> "Mur. testa parva, crassiuscula, fusiformi, cancellata, albo-lutescente: spira subproducta; anfractibus quinque; suturis foveolatis; cauda brevi, crassa, lata, ad terminum tortuosa, minime recurva; varicibus tribus, fimbriatis, crassis, costatis, utrinque foveolatis; ramis tubulatis, uno ad angulum crasso, valido, ad medium anfractus, uno brevissimo, caeteris obsoletis: interstitiis trifariam noduloso-costatis: apertura parva, integra, ovali; peritremate laevi; canali nisi ad extremitatem clauso." (Sowerby, 1841)

*Description*: Shell medium-sized; five postnuclear whorls; three varices and tubes per whorl; tubes within the varices, pointing apically, abaxially, and abaperturally; varices convex, crenulated, crossed by three ribs; outer lip of constant width, crossed by three ribs; a partition above the aperture joining the varix to the corresponding varix of the preceding whorl; shoulder formed only above the varices; suture appressed in the interapertural areas and distinct above the varix; shell crossed by coarse spiral ribs; aperture ovate, pointed anteriorly, surrounded with a raised rim with a sinuous outer margin; anterior canal closed, broad, curving abaperturally.

Holotype: Brit. Mus. (Nat. Hist.).

Type locality: Cabo Catoche, Terr. Quintana Roo, Mexico (here designated).

*Occurrence*: Unnamed post-Caloosahatchee formation, Florida; Pleistocene. Western Atlantic and Caribbean Sea, Recent.

*Figured specimen*: USNM 646228; height 17.5 mm, maximum diameter 9.9 mm; locality TU 759. Other occurrences: TU locality nos. 803, R-99.

*Discussion*: The name *Murex cancellatus* Sowerby, 1841, being a primary homonym of *Murex cancellatus* Gmelin, 1791, the next available name for the form is *Typhis triangularis* A. Adams, 1856. Sowerby (1879, p. 26) declared that "*Murex*" *cancellatus* and "*Murex*" *canaliferus* Sowerby, 1841, were the same species, "the difference is only one of development." If this were the case then *canaliferus* would be available but the writer is of the opinion that Sowerby's two species are not the same and that *M. canaliferus* is probably the shell subsequently named *Pterynotus* (*Pterochelus*) *zealandicus iredalei* Fleming, 1962. *M. canaliferus* is definitely a *Pterochelus* at least, for it shows the two varical canals, typical of that group. The illustration given by Sowerby of *M. canaliferus* (1841, pl. 190, fig. 74) also shows a narrower siphonal canal than that of *M. cancellatus* (*ibid.*, pl. 190, fig. 79). Keen (personal communication) has examined the type of "*Typhis*" *triangularis* in the British Museum (Nat. Hist.) and is satisfied that this is the same species as "*Murex*" *cancellatus* Sowerby.

Neither "*Murex*" *cancellatus* nor "*Typhis*" *triangularis* were described with locality data, but it has been established that the form is native to the western Atlantic region. In the Tulane Collections there are numerous beach specimens from the eastern Yucatán Peninsula. One specimen was dredged by the *Anton Bruun* Cruise 10 about 30 miles off Cabo Catoche, Quintana Roo (TU R-99) in 17 fms., and as there are a number of beach specimens from this vicinity, Cabo Catoche is here designated as the type locality. The species also occurs in the Bahama Islands and on the Atlantic Coast of Panamá, and is found in the Pleistocene beds of southern Florida.

*P.* (*T.*) *triangularis* most closely resembles *P.* (*T.*) *lowei* Pilsbry, 1931, from the west coast of Panamá. The two differ in that the former has stronger ribbing and a higher spire.

## V. Locality Data

The following are Tulane University Department of Geology fossil localities:

60. Jackson Bluff Fm., borrow pits at Jackson Bluff, Ochlockonee River (NW ¼ Sec. 21, T1S, R4W), Leon Co., Florida.
69. Shoal River Fm., type locality, Shell Bluff, Shoal River (NW ¼ Sec. 4, T3N, R21W), about 3½ miles north of Mossyhead, Walton Co., Florida.
69A. Shoal River Fm., first ravine upstream from Shell Bluff, Shoal River (NW ¼ Sec. 4, T3N, R21W), about 3½ miles north of Mossyhead, Walton Co., Florida.
70. Chipola Fm., Ten Mile Creek, at bridge of Florida Highway 73 (NW ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.
72. Jackson Bluff Fm., Alum Bluff (upper beds), Apalachicola River (NE ¼ Sec. 24, T1N, R8W), Liberty Co., Florida.
75. Moodys Branch Fm., type locality, Jackson, Hinds Co., Mississippi.
76. Mint Springs Marl, type locality, Mint Springs Bayou, just off U. S. Highway 61 (Business), at Vicksburg Natl. Military Cemetery, Vicksburg, Warren Co., Mississippi.
78. Gosport Sand, Claiborne Bluff, east bank of Alabama River, south of bridge of U. S. Highway 84, Monroe Co., Alabama.
79. Caloosahatchee Fm. and unnamed post-Caloosahatchee formation mixed, spoil banks north and south side of Caloosahatchee River, at Ortona Lock (Sec. 27, T42S, R30E), Glades Co., Florida.
85. Wautubbee Fm., roadcut on county road four miles northeast of Rose Hill, Jasper Co., Mississippi.
86. Wautubbee Fm., roadcut on east side of Mississippi Highway 15, 0.8 mile north of junction with U. S. Highway 80, Newton Co., Mississippi. (Note: Interstate 20 has subsequently covered this locality and it is no longer available.)
196. Chipola Fm., Ten Mile Creek, about ¼ mile upstream from bridge of Florida Highway 73 (NE ¼ Sec. 11, T1N, R10W), Calhoun Co., Florida.
200. Pinecrest Beds, borrow pits about one mile southwest of Acline (Sec. 29, T41S, R23E), Charlotte Co., Florida.
202. Caloosahatchee Fm., south bank of Caloosahatchee River, about two miles west of LaBelle (SE ¼ Sec. 12, T43S, R28E), Hendry Co., Florida.
203. Caloosahatchee Fm., north bank of Caloosahatchee River, about two miles east of Fort Denaud (SW ¼ Sec. 11, T43S, R28E), Hendry Co., Florida.
226. Red Bluff Clay, Chickasawhay River at Hiwannee about 3½ miles south of Shubuta, Wayne Co., Mississippi.
335. Byram Marl, roadcut on U. S. Highway 61 (Business), about one mile north of Vicksburg Natl. Military Cemetery, Vicksburg, Warren Co., Mississippi.
336. Byram Marl, above waterfall on small creek crossing U. S. Highway 61 (Business), about 1½ miles north of Vicksburg Natl. Military Cemetery, Vicksburg, Warren Co., Mississippi.
376. Duplin Marl, "Natural Well," sinkhole on Matthews' farm, on North Carolina Highway 11, 2 miles west of Magnolia, Duplin Co., North Carolina.
456. Chipola Fm., Ten Mile Creek, about ¼ mile downstream from bridge of Florida Highway 73 (NW ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.
457. Chipola Fm., west bank of Chipola River, about ½ mile below Ten Mile Creek (SW ¼ Sec. 17, T1N, R9W), Calhoun Co., Florida.
458. Chipola Fm., east bank of Chipola River, above Farley Creek (SW ¼ Sec. 20, T1N, R9W), Calhoun Co., Florida.
519. Caloosahatchee Fm., Harney Pond Canal spoil banks, at Florida Highway 78, northwest side of Lake Okeechobee (NW ¼ Sec. 18, T40S, R33E), Glades Co., Florida.
520. Pinecrest Beds, spoil banks, canal 0.9 mile east of Brighton on Florida Highway 70 (Sec. 25, T37S, R32E), Highlands Co., Florida.
523. Pinecrest Beds, Harney Pond Canal spoil banks, six miles northwest of Florida Highway 78, Brighton Indian Reservation (NW ¼ Sec. 22, T39S, R32E), Glades Co., Florida.
527. Caloosahatchee Fm., north shore Lake Okeechobee, Pumping Station no. 127 (NE ¼ Sec. 35, T39S, R33E), Glades Co., Florida.
529b. Caloosahatchee Fm., north bank of Caloosahatchee River, about two miles west of LaBelle (SE ¼ Sec. 12, T43S, R28E), Hendry Co., Florida.
532. Pinecrest Beds, spoil banks 1¾ miles south of Florida Highway 771, on canal 1.3 miles southwest of Port Charlotte Railroad Station (formerly Murdock), (SE ¼ Sec. 24, T40S, R21E), Charlotte Co., Florida.
536. Caloosahatchee Fm., south bank of Caloosahatchee River about one mile east of LaBelle (Secs. 3 and 4, T43S, R29E), Hendry Co., Florida. (Designated as type locality of the Caloosahatchee Formation by Olsson *in* Olsson and Petit, 1964, p. 519.)
539b. Caloosahatchee Fm., Shell Creek (lower beds), about eight miles east of Cleveland (Sec. 30, T40S, R25E), Charlotte Co., Florida.
540. Pinecrest Beds, Miami Canal spoil banks, one to three miles south of pumping station at Palm Beach county line, Broward Co., Florida.
546. Chipola Fm., Ten Mile Creek about 1½ miles west of Chipola River (NE ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.
547. Chipola Fm., west bank of Chipola River, about 2000 ft. above Four Mile Creek (SW ¼ Sec. 29, T1N, R9W), Calhoun Co., Florida.
554. Chipola Fm., east bank of Chipola River at power line crossing (SW ¼ Sec. 17, T1N, R9W), Calhoun Co., Florida.
555. Chipola Fm., east bank of Chipola River,

about 1000 ft. above Four Mile Creek (SW ¼ Sec. 29, T1N, R9W), Calhoun Co., Florida.

558. Waccamaw Fm., borrow pits at north end of Crescent Beach Airport, Crescent Beach, Horry Co., South Carolina.

579. Caloosahatchee Fm., Miami Canal spoil banks, four miles north of pumping station at Broward county line, Palm Beach Co., Florida.

583. Caloosahatchee Fm., Miami Canal spoil banks, seven miles north of pumping station at Broward county line, Palm Beach Co., Florida.

638. Agueguexquite Fm., roadcut and quarry on Mexico Highway 180, 14 miles east of junction with side road into Coatzacoalcos, Veracruz, Mexico.

655. Chipola Fm., Ten Mile Creek, about 0.1 mile downstream from bridge of Florida Highway 73 (NW ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.

705. Bowden Fm., type locality, Bowden, Parish of St. Thomas, Jamaica.

708. Chipola Fm., at small waterfall on tributary to Ten Mile Creek, south bank, about ¼ mile downstream from bridge of Florida Highway 73 (NW ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.

709. Chipola Fm., south bank of Ten Mile Creek, about ¼ mile downstream from bridge of Florida Highway 73 (NW ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.

710. Chipola Fm., Ten Mile Creek, just upstream from Mayo Mill Branch (NE ¼ Sec. 11, T1N, R10W), Calhoun Co., Florida.

710. Chipola Fm., Ten Mile Creek, just upstream from Mayo Mill Branch (NE ¼ Sec. 11, T1N, R10W), Calhoun Co., Florida.

726. Caloosahatchee Fm., Hendry County rockpit, ½ mile north of Florida Highway 80, three miles west of LaBelle (SE ¼ Sec. 14, T43S, R28E), Hendry Co., Florida.

728. Pinecrest Beds, spoil banks on west side of Kissimmee Canal and east side of Kissimmee River, just across from U. S. Corps of Engineers Structure 65-D (Sec. 33, T36S, R33E), Okeechobee Co., Florida.

729. Pinecrest Beds, spoil banks on west side of Kissimmee Canal and east side of Kissimmee River, approximately ½ mile south of U. S. Corps of Engineers Structure 65-D (S½ Sec. 33, T36S, R33E), Okeechobee Co., Florida.

730. Pinecrest Beds, embankment of Seaboard Airline Railroad, just west of Kissimmee River (NW ¼ Sec. 20, T36S, R33E), Highlands Co., Florida.

736. Pinecrest Beds, spoil banks on south side of Florida Highway 70 and east side of Kissimmee River, Okeechobee Co., Florida.

755. Caloosahatchee Fm., Miami Canal spoil banks, 17.4 miles north of pumping station at Broward county line, Palm Beach Co., Florida.

757. Gatun Fm., roadcut on Boyd-Roosevelt Highway at junction of road to Refineria Panamá, S. A., just east of Cativa, Panamá.

767. Caloosahatchee Fm. and unnamed post-Caloosahatchee formation mixed, spoil banks north side of Caloosahatchee River, five miles west of Ortona Lock (NW ¼ Sec. 36, T42S, R29E), Glades Co., Florida.

768. Caloosahatchee Fm. and unnamed post-Caloosahatchee Formation mixed, spoil banks north side of Caloosahatchee River, 5½ miles west of Ortona Lock (NW ¼ Sec. 35, T42S, R29E), Glades Co., Florida.

769. Pinecrest Beds, spoil banks east side of Kissimmee River, 1½ to two miles south of U. S. Corps of Engineers Structure 65-D (NE ¼ Sec. 35, T36S, R33E), Okeechobee Co., Florida.

770. Pinecrest Beds and Caloosahatchee Fm. mixed, spoil banks west side of Kissimmee River, 1½ to 3½ miles north of Florida Highway 70 (Secs. 10, 14, 15, and 28, T37S, R33E), Highlands Co., Florida.

786. Chipola Fm., Ten Mile Creek, about 50 yards upstream from TU 196 or about ¼ mile upstream from bridge of Florida Highway 73 (NE ¼ Sec. 11, T1N, R10W), Calhoun Co., Florida.

787. Chipola Fm., Ten Mile Creek, about 1½ miles west of Chipola River (SE ¼ Sec. 12, T1N, R9W), Calhoun Co., Florida.

792. Caloosahatchee Fm., borrow pits just west of Florida Highway 80, about two miles southwest of LaBelle (SW ¼ Sec. 7, T43S, R29E), Hendry Co., Florida.

797. Pinecrest Beds, material exposed during construction of "Alligator Alley," 13.3 miles east of Florida Highway 29 (T49S, R32E), Collier Co., Florida.

806. Chipola Fm., west bank of Chipola River, about one mile south of powerline crossing (NW ¼ Sec. 20, T1N, R10W), Calhoun Co., Florida.

810. Chipola Fm., east bank of Chipola River, opposite mouth of Taylor Branch (SW ¼ Sec. 17, T1N, R9W), Calhoun Co., Florida.

817. Chipola Fm., south side of Ten Mile Creek, large gully on the property of Mr. A. Sexton (1967), (SE ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.

818. Chipola Fm., Farley Creek, 0.1 mile west of bridge of Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.

819. Chipola Fm., Farley Creek, 0.2 mile west of bridge of Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.

820a. Chipola Fm., Farley Creek (upper beds), at bridge of Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.

820b. Chipola Fm., Farley Creek (lower beds), at bridge of Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.

821. Chipola Fm., Farley Creek, 0.1 mile east of bridge of Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.

825. Chipola Fm., Farley Creek, at abandoned mill about ¼ mile west of bridge of Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.

827. Chipola Fm., Farley Creek, about ½ mile west of bridge of Florida Highway 275 (SE ¼ Sec. 20, T1N, R9W), Calhoun Co., Florida.
828. Chipola Fm., Farley Creek, just upstream from mouth of unnamed tributary about ¾ mile downstream from bridge of Florida Highway 275 (SE ¼ Sec. 20, T1N, R9W), Calhoun Co., Florida.
830. Chipola Fm., Ten Mile Creek, at power line crossing about one mile west of Chipola River (SE ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.
831. Chipola Fm., Ten Mile Creek, lowest beds exposed, slightly less than one mile west of Chipola River (SW ¼ Sec. 7, T1N, R9W), Calhoun Co., Florida.
866. "Silverdale Beds," pit on north side of Webb Creek and east side of unnumbered county highway, Silverdale, Onslow Co. North Carolina.
870. Waccamaw Fm., pits on east side of North Carolina Highway 130, 2.8 miles north of Old Dock School, Old Dock, Columbus Co., North Carolina.
923. Wautubbee Fm., hill on south side of county road paralleling Interstate 20 along north side, 0.3 mile west of Mississippi Highway 15, just north of Newton, Newton Co., Mississippi.
924. Wautubbee Fm., roadcut 2.7 miles east of Mississippi Highway 15 at Newton, on road to Poplar Springs Church, Newton Co., Mississippi.
932. Pinecrest Beds, east side of Kissimmee River (*i.e.*, canal) and ½ mile south of Seaboard Airline Railroad, south of Fort Basinger (SE ¼ Sec. 20, T36S, R33E), Okeechobee Co., Florida.
939. Caloosahatchee Fm. and unnamed post-Caloosahatchee formation mixed, south side of Caloosahatchee River, 5.2 miles west of Ortona Lock (NW ¼ Sec. 36, T42S, R29E), Glades Co., Florida.
950. Chipola Fm., Chipola River, west bank about 2000 ft. above Farley Creek (SW ¼ Sec. 20, T1N, R9W), Calhoun Co., Florida.
951. Chipola Fm., Ten Mile Creek, about 1¼ miles west of Chipola River (SE ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.
953. Moín Fm., type locality, Moín Hill, railroad cut and adjacent ditches on road to Sandoval, 4.5 km west of Puerto Limon, Costa Rica.
954. Moín Fm., hill cut immediately behind Standard Fruit Co. box factory, just west of cemetery at Pueblo Nuevo, about 2 km west of Puerto Limon, Costa Rica.
958. Gatun Fm., hill slope on east side of road from Boyd-Roosevelt Highway to Refineria Panamá, S. A., about ½ km north of junction, just east of Cativa, Panamá.
975. Caloosahatchee Fm., spoil banks, north side Caloosahatchee Canal, 0 to ½ mile west of center of former Lake Hicpochee (now drained), (unmapped area, T42S, R32E), Glades Co., Florida.
998. Chipola Fm., Ten Mile Creek, about 1¼ miles west of Chipola River (SE ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.

The following are Tulane University Department of Geology Recent localities:

R-99. *Anton Bruun* Cruise 10, dredged off northeastern Yucatán Peninsula, Long. 86° 34′W, Lat. 21° 41′N, 17 fathoms.
R-100. *Anton Bruun* Cruise 10, dredged off Duarte Cays, northwest of Porto Bello, Panamá, Long. 79°40′W, Lat. 9°36′N, 23-27 fathoms.
R-101. *Anton Bruun* Cruise 10, dredged off Holandes Cay, east of Cape San Blas, Panamá, Long. 9°35′N, Lat. 78°48′W, 23-28 fathoms.

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December 29, 1969

# RECENT BOOKS

CLAY IN ENGINEERING GEOLOGY, by Jack E. Gillott. Published by Elsevier Publishing Company, Amsterdam, London and New York, 1968, xvi + 296 pp., $21.50

Clays, their classification, origin, composition, physical chemistry, moisture interaction, strength, elasticity, plasticity, viscosity, and other properties are comprehensively and definitively treated in this text devoted to the importance of clays to engineering geology. The concluding chapters deal with mineralogical, physical, and engineering analysis methods of clays and soils. The stated purpose of this book is to introduce geologists and mineralogists to soil mechanics and the terminology in this field, and to introduce engineers to the geology and mineralogy of clays. It presents a valuable summary of the present knowledge of clays in comprehensible and readable style.

MIGMATITES AND THE ORIGIN OF GRANITIC ROCKS, by K. R. Mehnert. Published by Elsevier Publishing Company, Amsterdam, London and New York, 1968, x + 393 pp., $26.00

This volume deals primarily with the petrography and genesis of migmatites. Such rocks are widely distributed in the crust, but their nature, origin and great importance to the theory of petrogenesis have been recognized only recently; no previous textbook

restricted to these complex rocks has been published. Discussion of megascopic structures and microfabric of migmatites is followed by consideration of experimental petrochemistry, geological thermometry, migration of mobile components within the crust, and the geochemistry of granitic rocks. In the concluding section, the theories of origin of granites and migmatites are explored, including magmatic formation, anatectic formation, and metasomatic formation of granitic rocks. Numerous photographs and drawings illustrate the conspicuous penetrating structures of migmatites. In the appendix, the complicated terminology of migmatites is summarized with definitions of the terms used currently in migmatite nomenclature.

A PETROGRAPHY OF AUSTRALIAN IGNEOUS ROCKS, by Germaine A. Joplin. Published by American Elsevier Publishing Company, Inc., New York, 1968, xiv + 214 pp., $8.50

Following discussions of classification and nomenclature, the igneous rocks of Australia are systematically described and illustrated by petrographic micro-drawings selected as typical examples of Australian rock types. The rocks are arranged according to type of magma so that suites of rock types related in origin rather than composition are together. Tables for identification are included.

A PETROGRAPHY OF AUSTRALIAN METAMORPHIC ROCKS, by Germaine A. Joplin. Published by American Elsevier Publishing Company, Inc., New York, 1968, x + 262 pp., $12.50

This book treats the Australian metamorphic rocks in a manner similar to that in the companion volume described above. It begins with discussions of metamorphic processes, nomenclature and classification, followed by description of Australian metamorphic rocks arranged according to their mode of origin. Thirty-five tables of chemical analyses and 191 petrographic microdrawings of rock types are included.

BASALTS: The Poldervaart Treatise on Rocks of Basaltic Composition, edited by H. H. Hess and the late Arie Poldervaart. Published by Interscience Publishers (John Wiley & Sons), New York, London and Sydney, 1967-1968, vol. 1, xvi + 482 pp., index, $22.00; vol. 2, viii + p. 483-862, index, $22.00

The basaltic rocks are the most widespread type of igneous rocks. This work, the first comprehensive treatise on basalts, was planned and organized by Arie Poldervaart before his untimely death in 1964. Poldervaart asked Harry H. Hess to take over the work of editing the contributions of the 22 authors which appear in the finished volumes, if he did not survive to see them completed.

Volume one deals with the forms and structures, mineralogy, petrography, and geochemistry of basaltic rocks, the silicate systems, and the effects of high pressure, water and oxygen pressures on crystallization of basaltic magmas. The second volume considers physical properties of basalts, cooling and solidification, spatial relations in island arcs, rhythmic and cryptic layering in plutons, differentiation of basalt magmas, andesites, spilites, eclogites, metamorphism of mafic rocks, and concludes with the origin of basaltic magmas.

MINERAL SPECIMENS, edited by C. J. Morrissey. Published by American Elsevier Publishing Company Inc., New York, 1968, 210 pp., $18.00

*Mineral Specimens* is a handsome atlas of full color photographs of 100 natural minerals, each with a page of descriptive information, listing composition, crystal habit, physical and optical properties, identifying features, occurrence and uses. Only specimens showing the typical appearance were chosen to illustrate each mineral; those presented were selected for their economic importance, importance as constituents of rocks, or spectacular appearance. The simplified presentation should be of interest to the amateur collector as well as to the professional geologist and mineralogist. —H.C.S.

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December 29, 1969

# SOME FORAMINIFERS OF THE GENUS *REOPHAX* AND DESCRIPTION OF A NEW GENUS[1]

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and
PEDRO J. BERMÚDEZ[3]

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## I. ABSTRACT

*Reophax caribensis*, sp. nov., is described. It is provided with a friable test composed of poorly cemented grains, generally laminar, and lives in shallow waters. It is compared with similar species, especially with *R. dentaliniformis* Brady.

*Glaucoammina*, gen. nov., is described and included in the family Lituolidae. The type species is *Reophax trilateralis* Cushman. This foraminifer is very variable in shape and lives on the outer submarine shelves of the Caribbean Sea. The test is composed of well cemented grains, mainly of glauconite, calcite, or dark minerals, or a combination of these.

## II. INTRODUCTION

During the summers of 1966 and 1967, staff members of the Puerto Rico Nuclear Center made sampling collections on the insular platform between Guanajibo and Añasco Bay, off the west central coast of Puerto Rico. At some stations, a great number of specimens of two arenaceous foraminifers of the genera *Reophax* and *Glaucoammina*, gen. nov., were found. The morphological characteristics of these foraminifers have never been clearly described and their distribution is related to interesting characteristics of the environment in which they live. The purpose of the work is to study their morphology, pointing out differences and affinities with other similar species, and their most significant relationships with the environment. The characteristics of some similar species have been revised.

*Reophax* is a foraminifer genus of very simple form, constituted of a linear series of chambers. This, along with the agglutinated walls, makes it difficult to establish specific differences. The evaluation of morphological characteristics requires a study of the population. This type of study may also contribute to the knowledge of the ecology of the species.

The authors are indebted to Dr. Ruth Todd of the U. S. Geological Survey and Drs. Richard Cifelli and Martin L. Buzas, for the facilities given to George A. Seiglie at the U. S. National Museum. Thanks are due also to Mrs. Vilma Román de Vega and to Frank G. Lowman of the Puerto Rico Nuclear Center for translating the manuscript into English.

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## III. Locations

Most of the foraminifers used in this study were found off the central west coast of Puerto Rico at the outer edge of Mayagüez Bay. Station 49: 18° 12′ 42″ N. latitude, 67° 11′ 10″ W. longitude, 13 meters depth. Station 69: 18° 13′ 30″ N., 67° 12′ 15″ W., 76 meters depth. Station 66: 18° 13′ 10″ N., 67° 13′ 05″ W., 128 meters depth. Station 95: 18° 13′ N., 67° 12′ 45″ W., 74 meters depth.

Station 12-6315 is located to the north of Los Testigos Islands, off the eastern coast of Venezuela, 11° 29′ N. and 63° 11′ W., 73 meters depth.

*Atlantis* station 2695, off the north Cuban coast is located at 23° 24′ N. and 81° 06′ 30″ W., 1107 meters depth.

## IV. Systematics

### Family Hormosinidae

### Genus *Reophax* Montfort, 1808

### *Reophax arayaensis* Bermúdez and Seiglie

Text figure 34

*Reophax scorpiurus* Montfort. Cushman, 1920, U. S. Natl. Mus. Bull. 104, pl. 1, fig. 5 (not figs. 6 and 7) (in part not Montfort, 1808).
*Reophax arayaensis* Bermúdez and Seiglie, 1963, Univ. Oriente, Oceanogr. Inst., Bol., v. 2, p. 146, pl. 1, figs. 1-3.

*Remarks.*—This species has some apparent similarities to *Glaucoammina trilateralis* (Cushman) [= *Reophax trilateralis* Cushman]. However, *Reophax arayaensis* is a true *Reophax*, totally uniserial. Secondly, the first chamber is in the narrower part of the test, which is tapering; this does not occur in *Glaucoammina trilateralis*. Thirdly, *Reophax arayaensis* lives in shallow waters, generally from 18 to 37 meters depth. The specimens referred by Cushman (1920) to *R. scorpiurus* are from Montego Bay, Jamaica, at 18 meters depth, (text figure 34). The habitat of *Glaucoammina trilateralis* is discussed below.

The transverse section of this foraminifer is triangular; however, it is not due to the disposition of the chambers, but rather to the form of the grains that adhere to the test. The grains are tabular and of relatively large size. The foraminifers of the genus *Reophax* that affix tabular or laminate grains to their tests, generally have a polygonal transverse section. The polygonal section is more resistant mechanically than is the triangular one.

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### Text Figures 1-20

1-12 *Reophax caribensis*, sp. nov. Sta. 49, Mayagüez Bay, depth 13 meters; 1) paratype, length 0.96 mm; 2) holotype, length 1.36 mm; 3-12 paratypes; 3) length 1.03 mm; 4) length 0.88 mm; 5) length 1.10 mm; 6) length 0.51 mm; 7) length 1.04 mm; 8) apertural view; 9) length 0.98 mm; 10) length 0.97 mm; 11) length 0.90 mm; 12) length 0.81 mm.

13,14 *Reophax caribensis*, sp. nov. Gulf of Paria, Trinidad, depth 4 to 33 meters; Cushman Coll., USNM 64754; 13) length 0.87 mm; 14) length 0.68 mm (figured also by Todd and Brönnimann, 1957, pl. 1, fig. 19).

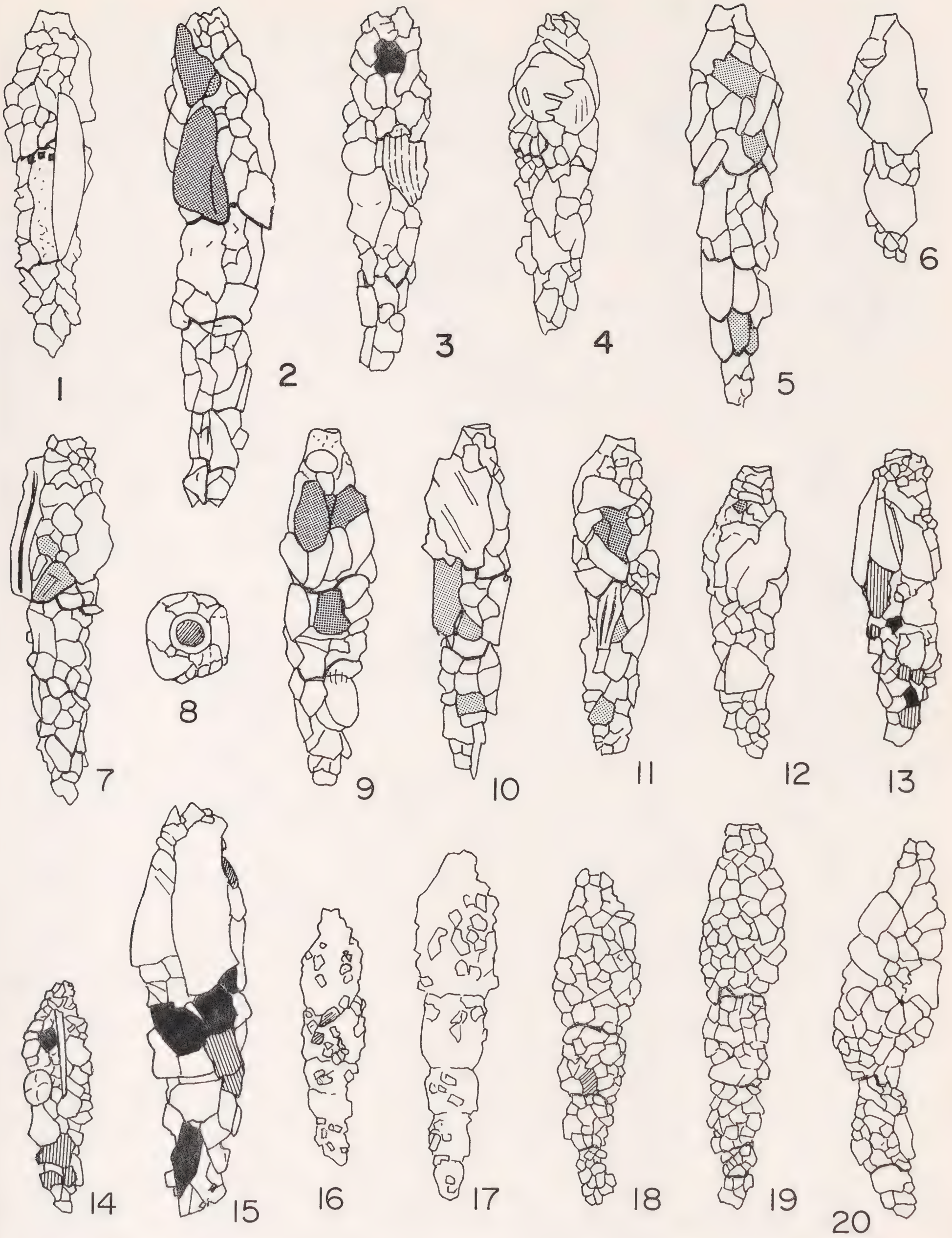
15 ? *Reophax caribensis*, sp. nov. Gulf of Mexico, depth 55 meters; Cushman Coll., USNM; length 1.21 mm (figured also by Phleger and Parker, 1951, pl. 1, fig. 6).

16 *Reophax caribensis*, sp. nov. USNM 641393; schematic drawing, length 1.04 mm (figured also by Buzas, 1965, pl. 1, fig. 1).

17 *Reophax dentaliniformis* Brady. Gulf of California, depth 285 meters; USNM 643347; schematic drawing, length 1.39 mm (figured also by Phleger, 1964, pl. 1, fig. 1).

18,19 *Reophax dentaliniformis* Brady. *Albatross* Sta. 2550, Atlantic Ocean, depth 1980 meters; USNM 10174; 18) length 1.28 mm; 19) length 1.49 mm.

20 *Reophax dentaliniformis* Brady. *Albatross* Sta. D 2189, Atlantic Ocean, depth 1097 meters; USNM 10160; length 1.49 mm.




TEXT FIGURES 1-20

*Reophax* sp. cf. *R. pilulifer* Brady
Text figures 32, 33

*Remarks.*—Some specimens of this foraminifer have certain similarities to *Reophax dentaliniformis* Brady. It may be observed that the illustrated specimens have very globular chambers and the test is much larger and more solid than those of the specimens generally assigned to *R. dentaliniformis.*

*Reophax dentaliniformis* Brady
Text figures 17-20

*Reophax dentaliniformis* Brady, 1881, Quart. Jour. Micr., v. 21, p. 49; Brady 1884, Rept. Voy. *Challenger,* Zool., v. 9, p. 293, pl. 30, figs. 23, 24.

*Remarks*: At present, it is not possible to include a complete synonymy of this species with certainty, therefore only a reference to the original description is made. In that description the most significant specific characteristics are: "slightly ventricose segments, texture somewhat coarsely arenaceous . . . and not very rough externally." Brady (1884) pointed out that it is a deep water species and his illustrated specimens also show depressed sutures and grains of relatively uniform size. He explained that "under this name the dentaline-like modifications of *Reophax scorpiurus* have been grouped together." This is a vague expression because many *Reophax* species are dentaliniform.

Specimens of *Reophax dentaliniformis* illustrated by Cushman (1920) are similar to Brady's figure. These specimens may be grouped together morphologically with a great number of *R. dentaliniformis* deposited in the U. S. National Museum. Three of them are illustrated in this paper in text figures 18-20. The most important characteristics of this morphological group are: slightly curved or straight test, elongated chambers slightly ventricose, depressed sutures and agglutinated material consisting of grains of more or less uniform size, relatively coarse but with the surface not very rough.

Most of the specimens from the *Albatross* stations in the Atlantic Ocean mentioned by Cushman (1920) were examined by G. A. Seiglie in the U. S. National Museum. From these stations, the following ones contain specimens that are undoubtly *R. dentaliniformis*: D2160, D2212, D2679, D2562, D2392, D2111, D2115, D2039, D2231, D2018, D2550. Their depths range from 300 to 3730 meters. Most of the specimens from the shallower stations should be included in other species. Many stations have specimens that could be considered as *Reophax subfusiformis* Earland or in the group of *R. scorpiurus* Montfort.

*Reophax* sp. A

*Reophax dentaliniformis* Brady. Cushman, 1948, Cushman Lab. Foram. Res., Spec. Publ. no. 23, pl. 2, figs. 11, 12 (not Brady, 1884).

*Remarks.*—This species is represented in the U. S. National Museum by some specimens found off Greenland. They correspond to the Cushman Collection nos. 60067, 60217, 60355, and 59974 and U. S. Na-

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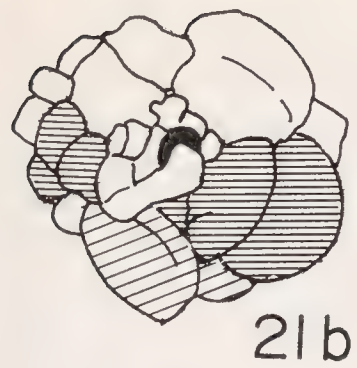
Text Figures 21-34

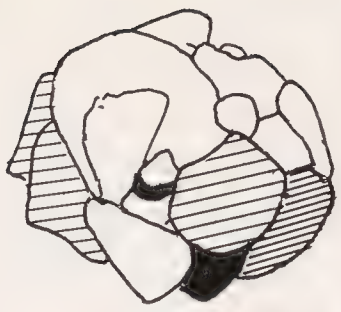
21-23 *Glaucoammina trilateralis* (Cushman). Sta. 12-6315 northwest of Los Testigos Banks, western Venezuela, depth 73 meters; 21 a-b) length 1.47 mm; 22 a-b) length 1.56 mm; 23 a-b) length 1.29 mm.

24-31 *Glaucoammina trilateralis* (Cushman). Sta. 66 and 69, at 128 meters and 76 meters respectively, close to Mayagüez Bay; 24) sta. 69, length 1.36 mm; 25) sta. 66, length 1.19 mm; 26 a-b) sta. 66, length 1.19 mm; 27) sta. 69, length 1.23; 28) sta. 69, length 1.17 mm; 29) sta. 66, length 1.29 mm; 30) sta. 66, length 1.27 mm; 31) sta. 66, length 1.18 mm.

32,33 *Reophax* sp. cf. *R. pilulifer* Brady. *Albatross* sta. D5637, Pacific Ocean, depth 1280 meters; Cushman Coll. 278; 32) length 2.74 mm; 33) length 3.76 mm.

34 *Reophax arayaensis* Bermúdez and Seiglie. Montego Bay, Jamaica, depth 18 meters; Cushman Coll. 66921; length 1.48 mm.


21b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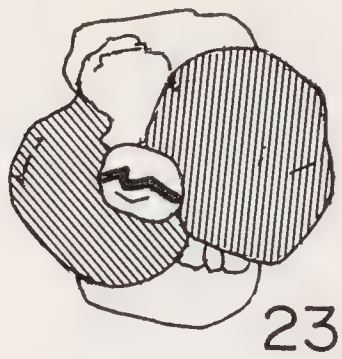
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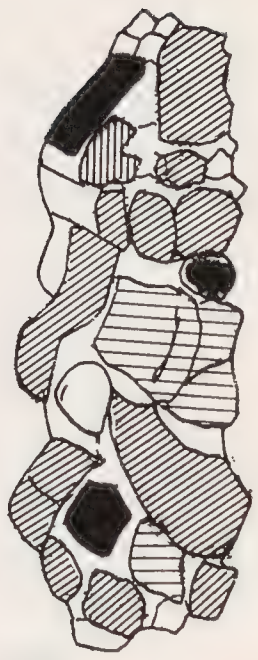
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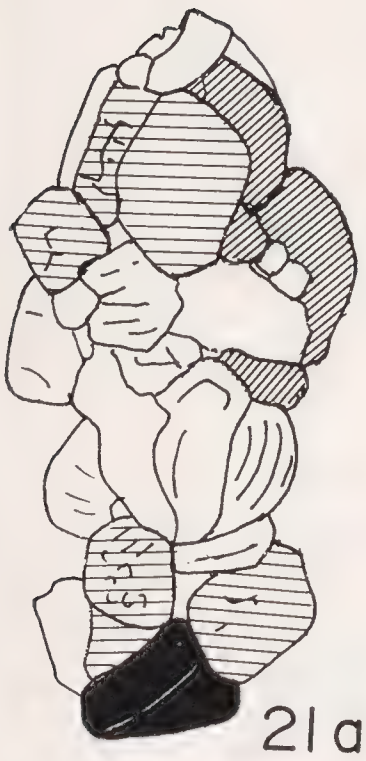
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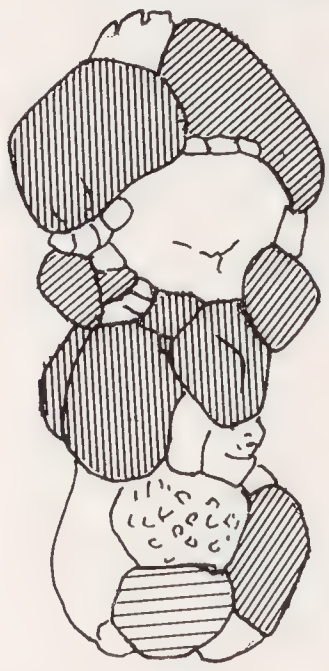
22a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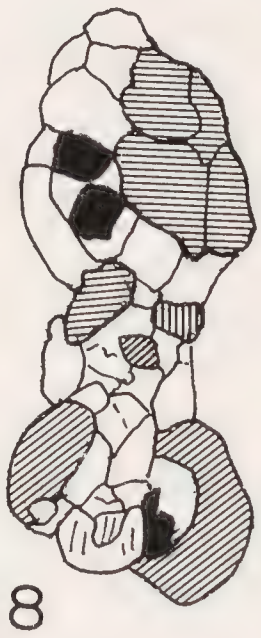
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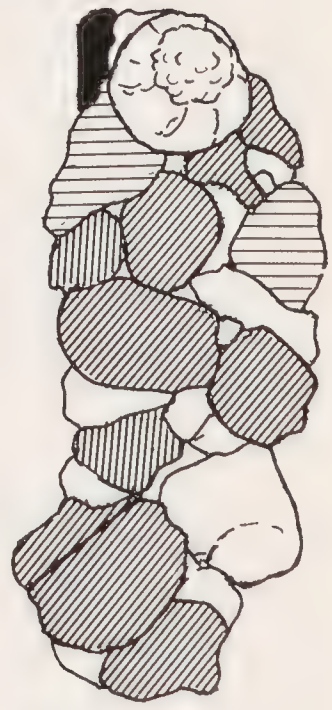
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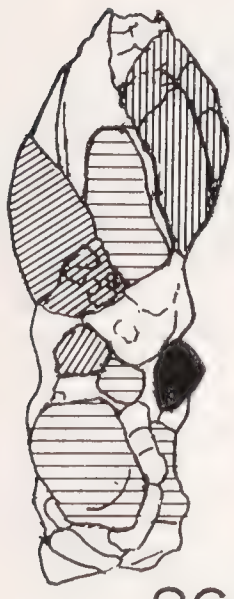
26a

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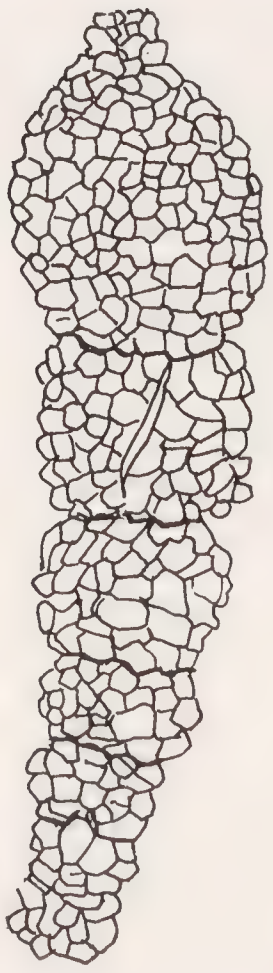
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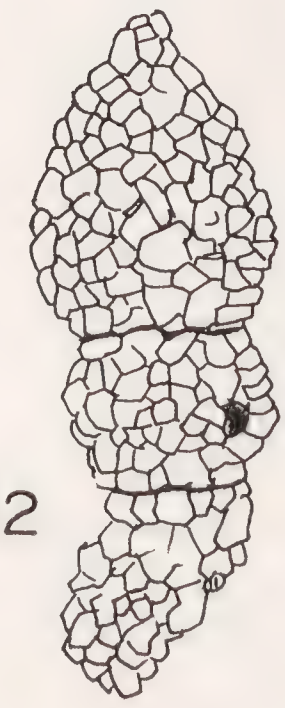
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TEXT FIGURES 21-34

tional Museum nos. 27967 and 27953. These specimens constitute a different morphological species: the test is of a smaller size, the chambers are shorter and irregular, and the surface is relatively more corrugated than in *Reophax dentaliniformis*. The illustrations by Cushman (1948) do not show the most important characteristics of the species.

A specimen from the Neny Fjord in Antartica illustrated by Cushman (1945, Proc. Amer. Phil. Soc., v. 89, pl. figs. 6, 7) as *R. dentaliniformis* is very similar to *R.* sp. A, but the chambers are more inflated.

*Reophax caribensis*, sp. nov.

Plate 1, figs. 5a-b; text figures 1-16

*Reophax dentaliniformis* Brady. PHLEGER and PARKER, 1951, Geol. Soc. America, Mem. 46, p. 2, pl. 1, fig. 1 (not Brady, 1884).

*Reophax dentaliniformis* Brady. TODD and BRONNIMANN, 1957, Cushman Found. Foram. Res., Spec. Publ. 3, p. 32, pl. 1, fig. 19 (not Brady, 1884).

[?] *Reophax dentaliniformis* Brady. BUZAS, 1965, Smithsonian Misc. Coll., v. 149, no. 1, p. 1-89 (? not Brady, 1884).

*Description.*—Test free, medium size, elongated, straight, spindle-shaped, with the first portion tapering. Four to six chambers slightly elongated, generally more or less polygonal in transverse section on account of the agglutinated grains of laminar shape. Sutures hardly distinguishable. Agglutinated wall formed by grains of very irregular shape and size, frequently laminar, mainly the largest ones; cementing material so scarce that the test is very fragile. Rounded aperture at the end of a short neck. Length 0.51 mm to 1.36 mm.

*Types.*—The holotype is represented by plate 1, figures 5a, b, and by text figure 2; the paratypes by text figures 1, and 3-12. The holotype and four paratypes are deposited at the U. S. National Museum, Washington D.C., and the other paratypes are at the Department of Geology, University of Puerto Rico, Mayagüez, Puerto Rico.

*Type locality.*—Station 49, Mayagüez Bay, Puerto Rico west coast, 18° 12′ 42″ N. latitude and 67° 11′ 10″ W. longitude, at 13 meters depth. The bottom sediments consist of gray silt and clay.

*Associated foraminifers.*—*Reophax caribensis* constitutes approximately 50% of the fauna of living foraminifers. The other more abundant living foraminifers are *Florilus grateloupii* (d'Orbigny) and *Fursenkoina pontoni* (Cushman).

*Remarks.*—Nearly 100 specimens of *Reophax caribensis*, sp. nov., were separated from part of a sample from the type locality. All of them are relatively uniform in size. Only one slightly curved specimen was observed, all the others are straight.

The scarcity of cementing material between the grains makes the tests very fragile and they break easily if the sample is heated for drying purposes. The tests cannot be transported from the shelf to deeper waters without destruction. *Reophax dentaliniformis* was reported by Brady (1884) and later by Cushman (1920) as a deep water foraminifer.

*Reophax caribensis*, sp. nov., is differentiated from *R. dentaliniformis* by its smaller size, non-ventricose chambers, poorly defined sutures, agglutinated material of very irregular size and shape, frequently laminar, and ecologic preference, as it lives in shallow waters.

It differs from *R. arayaensis* by its smaller size. The test has finer grains, chambers relatively shorter and they are not triangular

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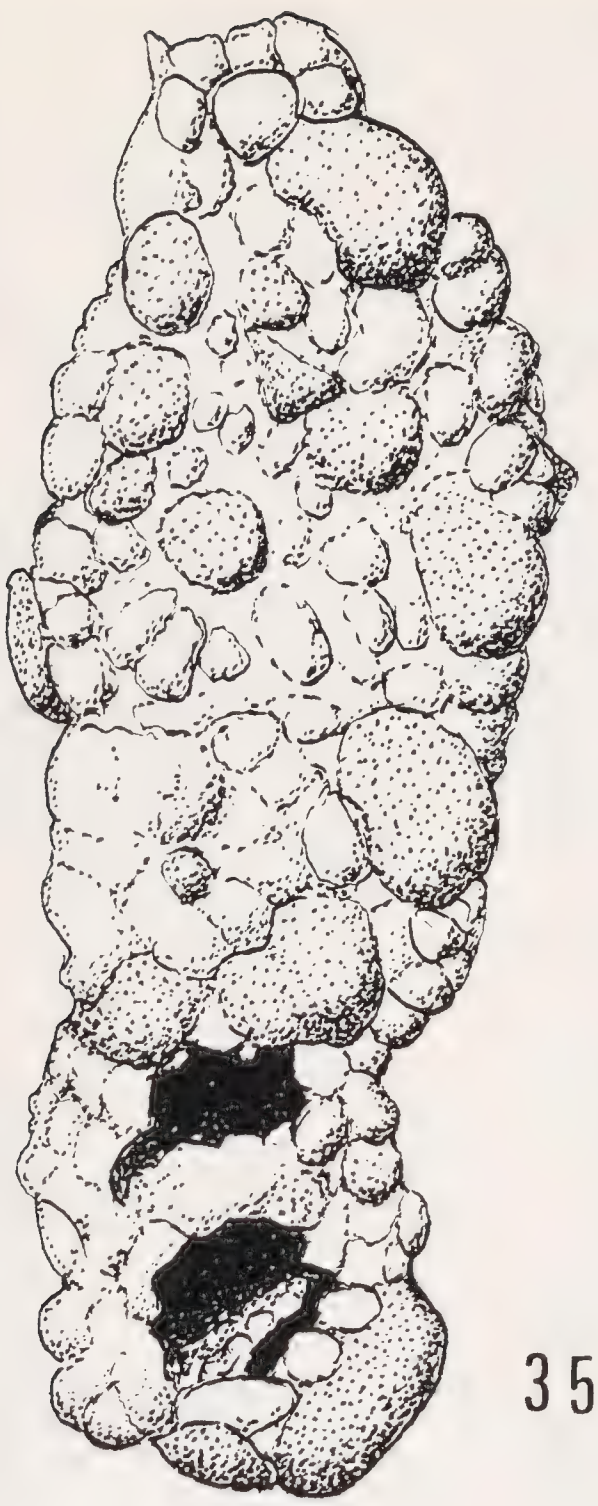
TEXT FIGURES 35-40

35 *Glaucoammina trilateralis* (Cushman). *Atlantis* Sta. 2981, off the north coast of Cuba; length 2.21 mm; orifice made with hydrochloric acid to show arenaceous septa and slightly twisted spiral.

36,37 *Glaucoammina trilateralis* (Cushman). Sta. 108, off the Caribbean coast of Panamá, 8° 50′ N. lat., 77° 25′ W. long., depth 82 meters; 36) length 1.48 mm; 37) length 1.27 mm.

38-40 *Glaucoammina trilateralis* (Cushman). 18° 31′ 05″ N. lat., 62° 02′ 15″ W. long., to 18° 30′ 30″ N. lat., 66° 04′ 05″ W. long., depth 466-549 meters; paratypes, USNM 26182; 38) length 1.11 mm; 39) length 1.36 mm; 40 length 1.48 mm.



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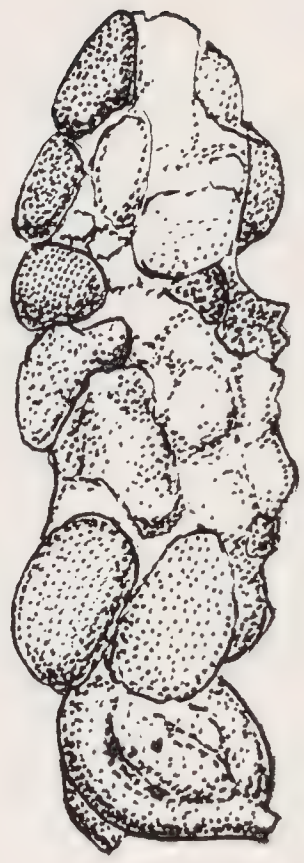

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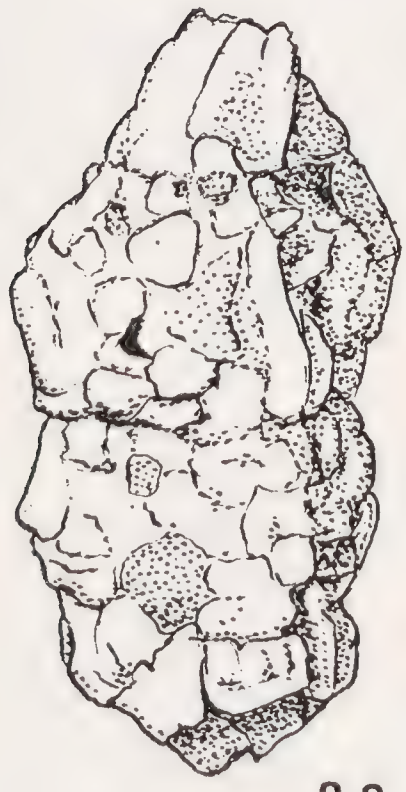

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TEXT FIGURES 35-40

in transverse section. The sutures of *R. arayaensis* are more compressed, and the test is more massively built and less fragile.

*Reophax scorpiurus* Montfort is a problematic species. Many authors do not agree which species represents Montfort's original figure (see Hoeglund, 1947). In any case, the morphological groups generally accepted as *R. scorpiurus* are very different from *R. caribensis*, sp. nov.

Specimens of this species were reported off Trinidad by Todd and Brönnimann (1957, plate 1, fig. 19) two of which are illustrated in this paper in text figures 13 and 14.

Phleger and Parker (1951) illustrated a specimen of *Reophax* from the Gulf of Mexico, refigured here in text figure 15, that is somewhat similar to this species, nevertheless it is relatively thicker than the specimens from the Caribbean Sea.

Seiglie (1967, figures 1 and 2) illustrated two specimens of *Reophax* from a sample to the northwest of Margarita Island, Venezuela, as *R.* sp. aff. *R. hispidulus* Cushman that looks like *R. caribensis*, but is differentiated by a longer neck provided with a lip.

Family LITUOLIDAE

*Glaucoammina*, gen. nov.

Type species: *Reophax trilateralis* Cushman, 1935.

*Description.*—Medium size test, elongated, first portion of test is thick, then it becomes narrower and then enlarges again. First chambers may be spiral, possibly the initial ones trochospiral, then triserial-uniserial or just uniserial; transverse section may be square-shaped, then triangular and then oval, triangular throughout, triangular and then oval, or irregular due to the irregular shape of the grains; the last chambers usually more or less compressed. Agglutinated wall, grains usually rather coarse; sutures in some cases poorly defined, but generally not distinguishable; septa agglutinated. Aperture is an elongated slit at the end of the neck in the last chamber.

*Remarks.*—The initial coarser portion of the test in this genus is similar to that of *Ammoscalaria* Hoeglund, 1947, but in this latter genus it is compressed and planispiral. The thickness of the first portion in *Glaucoammina* suggests that it is trochospiral, although the agglutinated septa that separate the chambers are easily crumbled making it difficult to observe the arrangement of the initial chambers. In plate 1, figure 11, and in text figure 35, the arrangement of the chambers may be observed.

This new genus differs from the genus *Ammoscalaria* in that it does not have secondary pseudochitinous septa; and it differs from *Triplasia* Reuss in that the triangular specimens are not uniserial.

The forms of the genus *Flabellamminopsis* Malecki, 1954, are similar to those of *Glaucoammina*, gen. nov., but the former differs from the latter in having pronounced sutures. It is not triserial in any stage of development and its walls are pseudolabyrinthic.

---

→

PLATE 1

1-4,8 *Glaucoammina trilateralis* (Cushman). Sta. 95, Mayagüez Bay, depth 74 meters; 1) length 1.43 mm; 4) length 180 mm; 8) length 1.21 mm.

5a-b *Reophax caribensis*, sp. nov. Sta. 49, Mayagüez Bay depth 13 meters; holotype, length 1.36 mm.

6a-b,7,9 *Glaucoammina trilateralis* (Cushman). *Atlantis* Sta. 2995, off the north coast of Cuba, depth 1107 meters; 6a-b) length 2.25 mm; 7) length 2.10 mm; 9) length 1.88 mm.

10a-b-c, 11,12 *Glaucoammina trilateralis* (Cushman). *Atlantis* Sta. 2963, off the north coast of Cuba, depth 348 meters; 10a-b-c) length 1.84 mm; 11) length 1.43 mm, the orifices shown in the figure were made by dissolving the wall with hydrocloric acid, each orifice corresponds to a different chamber; 12) length 1.89 mm.

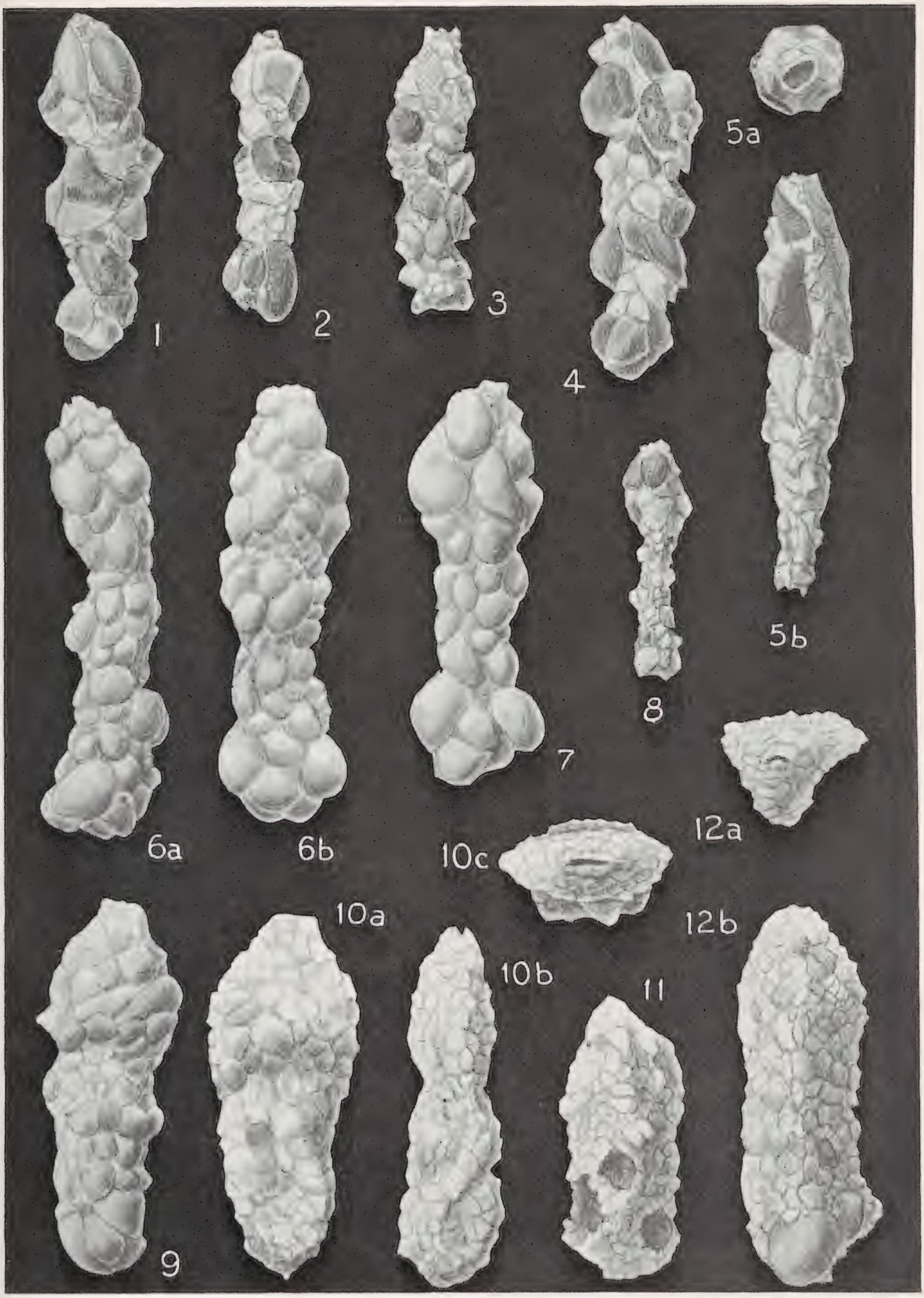


PLATE 1

*Glaucoammina trilateralis* (Cushman)

Plate 1, figs. 1-4, 6-12;
text figures 21-31, 35-40

*Reophax trilateralis* CUSHMAN, 1935 Smithsonian Misc. Coll, v. 91, no. 21, p. 91, pl. 1, figs. 1-4.

*Description.*—Test medium size; rounded, oval, square or triangular in transverse section. Early portion one large chamber or trochospiral, then it may be triserial and then uniserial or just uniserial; chambers relatively few, when uniserial there are two or three chambers after the early portion; sutures slightly depressed and only distinguishable in the uniserial part. Agglutinated wall coarsely arenaceous, formed by calcite grains or by glauconite pellets or by dark minerals, rarely other minerals; well-cemented. The opening is an elongated slit, generally at the end of a short neck. Length 1.00 to 2.27 mms.

*Remarks.*—This species is extraordinarily variable in shape, partly due to the diverse arrangement of the chambers. The forms based on this arrangement have been mentioned in the species description. The other factor that influences the shape is the grains of agglutinated material. Three main forms of this species were recognized and are described below.

The first form is constituted mainly of calcite grains. This is the nature of the specimens originally described by Cushman (1935). They are relatively smaller in size than the other two forms. The triangular and square section in the tests of the first type may be clearly seen on account of the small size of the grains (plate 1, figures 10-12).

The second form is constituted of glauconite pellets of relatively large size, in such a way that the transverse section is distorted (plate 1, figures 6 and 7; text figures 35-37). The specimen shown in plate 1, figure 9, is formed in part by calcite grains and by glauconite pellets.

The third form is mainly constituted of very coarse grains of dark minerals. Puerto Rican specimens contain grains of olivine, magnetite and pyroxene (plate 1, figures 1-4, 8, and text figures 24-31). The specimens from Venezuela (text figures 21-23) have coarse grains of dark minerals, some quartz and also glauconite; the last chamber is not compressed.

Living specimens were found in Puerto Rico between 50 and 80 meters depth.

The specimens illustrated in this paper were deposited in the U. S. National Museum, Washington, D. C.

*Localities and geological significance.*—This species has been found on the outer shelf of Puerto Rico in front of the bays of Mayagüez and Añasco and on the Cabo Rojo shelf at more than 20 stations, constituting up to 30% of the total population of benthonic foraminifers. The writers have also found specimens on the outer continental shelf of Venezuela, Colombia and Panamá. Some localities are mentioned in detail with the description of the figures. One of the writers has also examined specimens of this species in the U. S. National Museum, Cushman Coll. No. 14021 (as *Reophax scorpiurus* Montfort), from the China Sea, 14° 20′ 23″ N. latitude and 120° 34′ 15″ E. longitude, at 51 meters depth.

The specimens described originally by Cushman (1935), off the north coast of Puerto Rico, and the specimens from *Atlantis* station 2963 and 2995, off the north Cuban coast, were found between 348 and 1108 meters depth. However, the Greater Antilles submarine slopes drop rapidly to depths of hundreds of meters and the foraminifers from the outer shelf are easily transported to the deeps. The specimens illustrated in plate 1, figures 6, 7 and 8, found at 1107 meters depth, are composed of oxydized glauconite pellets, and it is known that glauconite is formed on the platforms. Thus it is very probable that the foraminifers attached the glauconite grains to the test when they were on the platform, being transported later to deeper waters.

It is important to mention that this species has been found on the platforms of Puerto Rico, Venezuela, Colombia and Panamá in places also suitable for the formation of glauconite. Mild anaerobic conditions and scarce sedimentation are necessary for the formation of glauconite. This explains the abundance of dark minerals in the tests and the scarcity of quartz, as this mineral is usually abundant where a high rate of continental sedimentation occurs. The presence of calcite grains also relates this fora-

minifer to areas of scarce sedimentation, such as the outer platform in front of the Caribbean reefs that produce carbonate sediments. In the Puerto Rican outer platform these foraminifers are found in Pleistocene sediments, also implying a low rate of Recent sedimentation.

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December 29, 1969

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# RECENT BOOKS

INTRODUCTION TO PALEOLIMNOLOGY, by C. C. Reeves Jr. Published by Elsevier Publishing Company, Amsterdam, London and New York, 1968, xii + 228 pp., $18.00

This book is the eleventh in the series, *Developments in Sedimentology*. Its purpose is to summarize the methods gathered from various disciplines applicable to the study of "fossil" lake basins, to popularize the study of ancient lake basins, and to emphasize their importance as indicators of paleoclimatology. Part one deals with the description of lake basins and their origin; part two, with the lake basins during water occupancy; and part three, with the paleolake basins, their distribution, cause and recognition, the Pleistocene chronology, and methods of determining and dating paleoclimatic parameters in ancient lake basins. —H.C.S.

THE PRESERVATION OF NATURAL HISTORY SPECIMENS: Volume Two, edited and compiled by Reginald Wagstaffe and J. Havelock Fidler. Published by Philosophical Library, New York, 1968, xvi + 404 pp., $17.50

The second and concluding volume of this work is concerned with the preservation of all types of vertebrate animals, botanical and geological specimens. Preparation of casts of reptiles and amphibians and modeling of large vertebrates and relief maps are definitively treated. Extensive appendices include information on instruments, microscopy, preservatives, methods of labelling, storing and maintenance of collections.

OPTICAL OCEANOGRAPHY, by N. G. Jerlov. Published by Elsevier Publishing Company, Amsterdam, London and New York, 1968, xvi + 194 pp., $13.50

This book is a review of current knowledge about the optics of the sea. The physical aspects and the relationship of optics to oceanography are emphasized. Thermodynamics, underwater photography and underwater television have been excluded from consideration. In part I, inherent optical properties of sea water are described; part II deals with underwater radiant energy; and, in part III, applications of optical methods to physical oceanography and to marine biology are discussed. —H.C.S.

PROCEEDINGS OF THE SYMPOSIUM ON TIDAL INSTRUMENTATION AND PREDICTIONS OF TIDES; published by l'Association internationale d'oceanographie physique and UNESCO. Symposium was May 3–7, 1965 in Paris, France. Publication date 1967. This is Scientific Publ. # 27 of the AIOP, 243 pp., $8.50.

The papers contained within this symposium volume are almost equally divided between the two topics, i.e., fifteen on tidal instrumentation and thirteen on analysis and prediction of tides. Authors of papers came from France, United States, Finland, Canada, Japan, Italy, Germany, and England but English and French must have been the official languages for the presidential address and eight of the technical papers are in French, with the remainder in English. They constitute a distinguished group, with most of the men prominent in this field represented here.

The book, although softbound, is printed on a good quality paper and the illustrations, dominantly line drawings but including many half-tone photographs, are well done. The diversity of devices and techniques precludes any detailed review—but also guarantees something of value to people working in this area of knowledge. Such symposia, and the reports which result from them, as well as the personal contacts between scientists at the meetings, aid greatly in speeding the spread of information. —H.M.J.

ENGINEERING PROPERTIES OF ROCKS; by I. W. Farmer. Published by E. & F. N. Spon, Ltd., London and distributed in the United States by Barnes & Noble, Inc., 105 Fifth Avenue, New York City. Nov. 19, 1968, x + 180 pp., 76 figs., selected biblio., refs., index, $5.75.

In his preface, the author says, "The book is intended primarily for civil and mining engineers familiar with the processes of design and construction in rock . . . and for students of engineering and engineering geology. I have attempted to present a simple, concise and reasonably comprehensive introduction to some of the theoretical and empirical criteria which may be used to define rock as a structural material."

He has accomplished his purpose ably. In addition, his chapter on "elastic properties of rocks" should be helpful to any seismologist interested in more than just coloring lines on records and his chapter on "stress and strain," with its excellent discussion of the Mohr diagrams, should be of value to the structural geologist.

For current use it is unfortunate that the author used metric units throughout, for the English-speaking engineer invariably works in English units. However, the author is to be congratulated for his use of a theoretical approach (where possible) but also in using an empirical approach where theory is not mathematical; as he says, "it is better to arrive rhetorically at a 10% error than theoretically at a 50% error—such is the nature of rock." A definite contribution to our knowledge of rock behavior, well indexed and referenced, and it will be of value in every research library. —H.M.J.

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TULANE STUDIES IN GEOLOGY AND PALEONTOLOGY

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# CENOZOIC MURICIDAE OF THE WESTERN ATLANTIC REGION PART V—*PTERYNOTUS* AND *POIRIERIA*

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## I. Abstract

This paper covers the two, closely related, most ancient muricine genera *Pterynotus*, including the subgenera *Pterochelus* and *Purpurellus*, and *Poirieria*, with the subgenera *Paziella*, *Flexopteron*, *Panamurex*, and a new subgenus *Pazinotus*, here named (type species: *"Eupleura" stimpsonii* Dall, 1889). In the New World *Pterynotus* and *Paziella* appear together in the Paleocene beds of Alabama; *Poirieria* s.s. first occurs in the lower Eocene of Alabama; *Pterochelus* and *Panamurex* are first seen in the Oligocene of Mississippi; and *Pazinotus* is first found in the (?) upper Miocene of Jamaica. All have at least one living representative in the Recent fauna of the western Atlantic region. *Flexopteron* first appears in the Oligocene of Germany and is represented in the New World by a single species from the (?) upper Miocene of Jamaica. There is no living representative of this subgenus. *Purpurellus* first occurs in the lower Miocene of North Carolina and is found in the Recent fauna only off the west coasts of Africa and tropical America.

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A total of 42 species are treated systematically. These include twelve assigned to *Pterynotus* s.s., two to *Pterochelus* and one to *Purpurellus*. Two species are assigned to *Poirieria* s.s., seven to *Paziella*, one to *Flexopteron*, two to *Pazinotus*, and fifteen to *Panamurex*. Of the total number ten are new species: *Pterynotus* (*Pterynotus*) *stenzeli*, from the early middle Eocene of Texas; *Poirieria* (*Poirieria*) *woodsensis*, from the lower Eocene of Alabama; *Pterynotus* (*Purpurellus*) *repetiti* from the early lower Miocene of North Carolina; *Pterynotus* (*Pterynotus*) *hoerlei* and *Poirieria* (*Panamurex*) *mauryae*, from the (?) late lower Miocene of Florida; *Poirieria* (*Paziella*) *septima* and *Poirieria* (*Panamurex*) *dubitalis*, from the (?) upper Miocene of Mexico; *Poirieria* (*Pazinotus*) *bowdenensis*, from the (?) upper Miocene of Jamaica; *Poirieria* (*Panamurex*) *gabbi*, from the middle Miocene of the Dominican Republic; and *Poirieria* (*Panamurex*) *velero*, from the Recent off northern South America. In addition, four homonyms are renamed. These are: *Pterynotus* (*Pterynotus*) *havanensis*, for *Murex tristichus* Dall *non* Beyrich; *Pterynotus* (*Pterynotus*) *bushae*, for *Murex pygmaeus* Bush *non* Schlotheim; *Poirieria* (*Paziella*) *harrisi*, for *Murex morulus* Conrad *non* Schröter; and *Poirieria* (*Panamurex*) *macneili*, for *Murex simplex* Aldrich non Philippi.

## II. Introduction

*PTERYNOTUS*: *Pterynotus* is one of the most ancient of the muricine genera. Together with *Poirieria* (*Paziella*) it appears in the Paleocene beds of Alabama. *Pterynotus* is a very conservative group and there has been little change from the Paleocene ancestor to the Recent species. The shell type with three wing-like varices was early recognized as a distinct unit and was among the first of the muricine subgenera to be separated. But there has been a great deal of confusion over which species should be included in the group. There are a number of species in the subfamily Ocenebrinae* that closely mimic the three-winged shape of *Pterynotus* and these almost invariably have been included even though they may be distinguished by the completely closed siphonal canal, by the purpuroid operculum, and by the different radular type. For the paleontologist these two latter characteristics are useless but the sealed canal is present in the fossils. The generic name *Pteropurpura* has been employed as a replacement name for the supposedly preoccupied *Pterynotus* but this name is for the alate members of the Ocenebrinae. The problems of synonymy in the name *Pteronotus* vs. *Pterynotus* has been discussed by several authors, including the writer (Vokes, 1964, p. 14) and most recently by Heppell (*in* Vokes, 1968b, p. 304). In addition to the substitute names proposed, there have been various genera erected that are not to be distinguished from the typical *Pterynotus*. The disposition of these names was covered by the writer in the above-mentioned work. One subgenus originally placed by her in the synonymy of *Pterynotus*, is not, however, to be included in that group. This is *Subpterynotus* Olsson and Harbison, which is now assigned to the genus *Murexiella* (Vokes, 1968a, p. 91).

The modern members of the genus *Pterynotus* are usually deep-water forms and are usually rare. Such is also the case in the fossil record, for although there are numerous species of *Pterynotus*, never are there more than a few specimens known, except during Eocene time when the *Pterynotus* group dominated the muricine world, especially in the Paris and London basins. In the New World they have never achieved a position of numerical importance.

*PTEROCHELUS*: The subgenus *Pterochelus* differs from *Pterynotus* s.s. in having a channeled spine at the shoulder, surrounded by the wing-like varix. The channel is almost closed in certain extreme species such as *P. angasi* (Crosse, 1863) and mimics the tube of the genus *Typhis*, but it usually remains open on the apertural side by a narrow slit. "*Typhis*" *zealandicus* Hutton, 1873, lacks the slit and also has the siphonal canal completely sealed in the typical typhine manner, but nevertheless seems to be a member of the *Pterochelus* group rather than the Typhinae. (It is not preoccupied by *Murex*

* Formerly Tritonaliinae, the International Commission on Zoological Nomenclature has ruled in Opinion 886 (Bull. Zool. Nomen., v. 26, pt. 3, p. 128, 1969) that the genus *Ocenebra* and subfamily Ocenebrinae are the names to be used for this group.

*zelandicus* Quoy and Gaimard, 1833, the type of *Poirieria.*) Morphologically this species seems more akin to the other members of *Pterochelus*, such as *P. angasi*, also originally named as *Typhis*, than to the members of *Tripterotyphis* Pilsbry and Lowe, 1932, the group of trivaricate typhines, which bear the tubes within the varix. (*Nothotyphis* Fleming, 1962, is considered a synonym of *Tripterotyphis.*) The shells referred to *Tripterotyphis* are all marked by a strongly cancellate surface unlike the smooth polished shells of *P. zealandicus* and *P. angasi.* The *Typhis*-like tube and closed anterior canal would seem to have arised by convergence, as suggested by Fleming (1962, p. 112). It is very possible that the Typhinae are polyphyletic and certain members of the subfamily are descended from a *Pterochelus* ancestor. As noted below under *Purpurellus*, the members of *Pterochelus* and *Purpurellus* are marked by a series of brown color spots along the margin of the outer lip. These same spots are seen in certain members of the Typhinae, such as *T. coronatus* Broderip, 1833, *T. grandis* A. Adams, 1855, (see Shasky and Campbell, 1964, pl. 21, figs. 1-3) *T. belcheri* Broderip, 1833, *T. sowerbii* Broderip, 1833, (see Sowerby, 1841, pl. 200, figs. 6, 8), and *T. expansus* Sowerby, 1874. All of these species are of the alate subgenera of *Typhis* and may represent a separate line from the spinose groups such as *Typhis* s.s.

*Pterochelus* first appears in the middle Eocene beds of the Paris Basin with the species "*Murex*" *caillati* Deshayes, 1865, (not preoccupied by *Murex cailleti* Petit, 1856) and also occurs in the upper Eocene and lower Oligocene beds of England and Germany with a similar form, *P. bispinosus* (J. de C. Sowerby, 1823). These two species are closely related but Wrigley (1930, p. 98) observed that *P. caillati* is "broader, with stronger spiral banding which often is granulated; and with five instead of two canals on the face of the varices. These canals, excepting the largest one at the rear, are separated from the aperture by a crimped and denticulated extension of the inner coat of the shell." *P. bispinosus*, as the name implies, has two spines on the apertural face of the varix and this same bispinose condition is present today in the Recent species of the group. The form achieved worldwide distribution in early Cenozoic time for a species, *P. angelus* (Aldrich), which is perhaps identical with *P. bispinosus*, is found in the lower Oligocene beds of Mississippi and *P. manubriatus* (Tate, 1888) occurs in the upper Eocene of Australia. The Recent distribution of the subgenus is principally Australian but there is one western Atlantic species and one eastern Pacific species.

The members of *Pterochelus* were probably shallow water inhabitants during the Eocene and Oligocene but in the New World they subsequently retreated to deeper water in later geologic time. Hence the group is unknown in the New World from the Oligocene until the Recent, although there is a species in the Pliocene Coralline Crag of England. In Australian waters there are several Recent species that live in depths of from 15 to 60 fathoms but there is little ecologic data available on the group as a whole.

*PURPURELLUS*: In a recent paper Emerson and D'Attilio (1969) have demonstrated that *Purpurellus* does possess a muricine radula as indicated by Thiele (1929, p. 289, fig. 313). In a previous work (Vokes, 1964, p. 26) the writer doubted the validity of Thiele's identification as the shell morphology of *Purpurellus* is more akin to the members of the subfamily Ocenebrinae. Because of the muricine nature of the radula (which is identical to the members of *Murex* s.s., *Chicoreus*, *Hexaplex*, and other "normal" Muricinae genera, but slightly different from the "abnormal" *Pterynotus*, an apparently degenerate form) Emerson and D'Attilio have removed *Purpurellus* from its position as a subgenus of *Pteropurpura* in the Ocenebrinae and placed it as a subgenus of *Pterynotus* in the Muricinae.

The writer (Vokes, 1968, p. 90) experienced a similar problem with the genus *Homalocantha*, which has a muricine shell morphology and radular type but a "purpuroid" (*i.e.*, lateral nucleus) operculum. In this case it was decided that the weight of evidence pointed to placement in the Muricinae in spite of the atypical operculum. In the case of *Purpurellus* the evidence is less clear-cut. The operculum of *Purpurellus* is unlike either the Muricinae or the Ocenebrinae, having an almost central nucleus (*Murex haustellum*, in the Muricinae, has

the only comparable operculum among the related species). The morphology of the shell is similar to both *Pterynotus* and *Pteropurpura* in certain respects, for those two genera are much alike as indicated above, but the nature of the circular aperture and the sealed siphonal canal would appear to be closer to *Pteropurpura* than to *Pterynotus*. It was this fact that caused the writer to make her original decision to place the group in the Ocenebrinae. However, confronted with this incontestable evidence of the radular similarity the group was re-examined from this point of view and it became obvious that the line was derived from a *Pterochelus* ancestor. The clue that pointed the way to this solution is the presence in both forms of the row of brown spots along the length of the outer lip from the suture to the tip of the canal. (Compare Emerson and D'Attilio, 1969, pl. 26, figs. 1, 5, and 7, with Vokes, 1966, pl. 25, fig. 3.) All of the species of *Pterochelus* and of *Purpurellus* seem to have these markings, although their exact *raison d'être* is not known at this time. Such a feature, so seemingly non-adaptive in nature, is highly suggestive of a common ancestor. In addition, there is considerable similarity in overall shell shape, both forms having the tendency toward a disruption in the varical flange at the base of the body whorl (compare Emerson and D'Attilio, 1969, pl. 27, fig. 11 with Vokes, 1966, pl. 25, fig. 1, for example). *Purpurellus* differs from *Pterochelus* in lacking the varical channels but there is a remnant fold at the shoulder. As a group *Purpurellus* is unique among the Muricinae in having a sealed siphonal canal (there are a few isolated species among other subgenera that also possess sealed canals), this apparently representing convergent evolution with the Ocenebrinae. This latter group is in all probability also descended from the *Pterynotus* line as there are no known Paleogene representatives of the Ocenebrinae.

The subgenus *Purpurellus* first appears in the lower Miocene of North Carolina, with the new species *P.* (*P.*) *repetiti*, described below. In the middle and upper Miocene and Pliocene of Europe there are several species of *Purpurellus*. In the Recent fauna the distribution is disjunct with the type ("*Murex*" *gambiensis* Reeve) coming from West Africa and the only other known species ("*Murex*" *pinninger* Broderip, 1833, of which "*Centrifuga*" *inezana* Durham, 1950, is a synonym, and *P. macleani* Emerson and D'Attilio, 1969) occurring on the West Coast of tropical America from Ecuador to the Gulf of California. It is not known if the first appearance of the group in the western Atlantic is indicative of its development here or if it is a result of lack of beds of the proper age and facies in the other parts of the world.

*POIRIERIA*: In a previous work (Vokes, 1964, p. 17) the writer discussed the reasons for distinguishing between the subgenera *Poirieria* s.s. and *Paziella*. Although there is considerable similarity of morphology between the two groups, in the members of *Poirieria* s.s. the outer lip opens directly into the varical spines, but in *Paziella* this labrum is closed and conspicuous denticles are formed. Both groups achieved worldwide distribution in the Eocene, but in the Recent fauna *Poirieria* s.s. is confined to the southern Atlantic and to the Pacific waters of Japan and New Zealand. Kira (1962, p. 65) referred two Japanese species to the subgenus *Bathymurex*, which this writer considers a synonym of *Paziella*. One of these, "*Trophonopsis* (*Bathymurex*)" *gorgon* (Dall, 1913) is especially close to *P. zelandicus* (Quoy and Gaimard, 1833), type of the genus, and is certainly to be referred to *Poirieria*. The second, "*Trophonopsis* (*Bathymurex*)" *echinus* (Dall, 1920), is only slightly less certain. Both are found in deep water off Japan.

*Poirieria* appears in the lower Eocene beds of Alabama and in the lower Eocene London Clay of England. The two Eocene forms are almost indistinguishable from the Recent *P. zelandicus* and demonstrate that the line had had a long, virtually unchanging, geologic history.

*PAZIELLA*: In the upper Paleocene of Alabama the species *Poirieria* (*Paziella*) *harrisi* Vokes (new name for *Murex morulus* Conrad non Schröter) occurs with *Pterynotus matthewsensis* (Aldrich). These two species are of two different, yet similar, genera and at this stage of generic divergence it is possible to recognize a common origin for the two groups. The first *Paziella* has six wing-like varices each bearing a strong shoulder

spine; the contemporaneous *Pterynotus* species also has six varices in the early post-nuclear stage but on about the second post-nuclear whorl these become three varices and three low intervarical nodes. Each of the three varices has a strong shoulder spine comparable to that of *Paziella*. The shells of both are smooth, almost totally unornamented except for the varices. Ideally the Cretaceous ancestor should be a small, smooth, multivarixed shell with an extended siphonal canal, but so far it has not been recognized in the New World. However, in the Cretaceous of Saxony there is an ideal prospect for the ancestor in the species named *Murex armatus* Geinitz (1875, Palaeontographica, v. 20, pt. 7, p. 263, pl. 59, fig. 16). This small species (the name of which is unfortunately preoccupied by *M. armatus* A. Adams, 1854, but it will not be renamed here) fits the above description perfectly. It is 6 mm in height, although it has five post-nuclear whorls and must be almost an adult. It has seven varices, each bearing a long spine at the shoulder, but the shell is otherwise smooth and unornamented. The holotype is broken but it clearly had a long, extended canal. This is the only known pre-Tertiary occurrence of a muricine species, although the name "*Murex*" has been applied to other Cretaceous (and even a few Jurassic) species. All of the latter are misidentifications, either as to the nature of the genus or the age of the strata. (For example, there is a good species of *Murex* s.s. that was reported from the "Cretaceous" of Brazil but this has subsequently proved to be Miocene in age.) But "*Murex*" *armatus* does seem to be an indisputable *Paziella* from the lower Pläner beds of Saxony, Cenomanian in age, and as such is the oldest known species of Muricinae.

Although the two subgenera *Poirieria* s.s. and *Paziella* may be separated by the presence of the labral denticles in *Paziella*, there is no such reason to separate two other taxa based on Caribbean species that are very close to *P. pazi* (Crosse, 1869), type of *Paziella*. Indeed, the type of *Bathymurex*, "*Murex*" *atlantis* Clench and Pérez Farfante, 1945, may be a synonym of *P. pazi*. According to Harvey R. Bullis, Jr. (personal communication), of the U. S. Bureau of Commercial Fisheries, there are two "varieties" of *P. pazi*. One is the relatively smooth typical form, which occurs in waters in the vicinity of the Antilles, and the second is a more heavily ornamented form, occurring on the Continental shelf from Texas to Florida. The holotype of *P. atlantis* is much like these ornamented specimens of *P. pazi*, and whether they represent two valid species or not is a subjective matter, but certainly they are of the same subgenus.

*P. nuttingi* (Dall, 1896), the type of *Dallimurex*, is also not to be separated from the typical *Paziella*. Rehder used his subgenus for forms having strongly developed spiral ornamentation that are herein referred to the subgenus *Panamurex*. Unfortunately his selection of the relatively smooth *P. nuttingi* as type negates this usage.

In the fossil record specimens of *Paziella* are very rare and it probably always has been a deeper water group. In the Recent fauna the species are for the most part confined to depths greater than 100 fathoms. The single known exception to this is the holotype of *P. nuttingi*, which is said to have been taken in 15 fathoms. In the depths these species are not rare, the U. S. Fish and Wildlife Service exploratory vessels have taken *P. pazi* at no less than 25 stations to the writer's knowledge.

*FLEXOPTERON*: Recently a new genus has been proposed by Shuto (1969, p. 111) for a new species *F. philippinensis*, from the upper Miocene of the Philippine Islands. The type of this new genus bears a remarkable resemblance to "*Murex*" *collatus* Guppy and it would seem that our Caribbean species should be placed herein. Shuto placed his new taxon in the family Coralliophilidae, due to the nature of the "umbilical and apertural features." One of the primary characters of the coralliophilids, however, is a markedly scabrous surface texture completely lacking in *Flexopteron*. For this reason it seems an untenable assignment and, in view of the number of similarities to *Poirieria* and *Paziella*, it would seem more likely that this new genus is most closely allied with these groups. *Flexopteron* differs from *Paziella* in lacking the pronounced shoulder spine, having instead a flanged varix, open at the shoulder. As is usually the case the differences between the two type species is immediately discernable, but in the

intermediate forms the demarcation is less clear-cut.

The oldest species that is referable to this group is "*Murex*" *deshayesii* Duchastel *in* Nyst, 1836, from the Oligocene of Central Europe. Although this species has been confused with "*M.*" *capito* Philippi, 1844, by several authors the forms are completely distinct. "*Murex*" *capito* is a true *Poirieria* with a single long open spine at the shoulder but "*M.*" *deshayesii* has the flanged varix of *Flexopteron*. "*Murex*" *octonarius* Beyrich, 1854, from the upper Miocene of Germany, and "*Murex*" *citimus* and "*M.*" *carcarensis* Bellardi, 1872, from the Miocene of Italy, are other species that should be placed in *Flexopteron*. There are no living species known to the writer.

*PAZINOTUS*: In this paper a new subgenus is erected for those few species that seem to be intermediate between *Pterynotus* and *Paziella*. They possess a variable number (about four to seven) of winged varices, which are formed by spines with a laminar flange connecting them. The aperture bears denticulations on the outer lip and on the whole the shell looks like a *Paziella* with winged varices. The type of the subgenus, "*Eupleura*" *stimpsonii* Dall, 1889, is found in water of about 100 fathoms depth. There is but a single fossil specimen in the western Atlantic region, from the Bowden Formation of Jamaica, which is thought to represent deep-water deposition. In addition, there are two species from the middle Miocene of Romania: "*Murex*" *giselae* and "*Murex*" *attonans* Boettger, 1901, (see Zilch, 1934, pl. 15), and one from the middle Miocene of France, "*Murex*" *typhioides* Mayer, 1869, to be referred to this group. "*Murex*" *funafutiensis* Hedley, 1899, described from 40 to 80 fathoms at Funafuti Atoll, Ellice Islands, is another Recent representative of the line.

The members of this new subgenus have been variously classified by authors as *Eupleura*, *Muricopsis*, or *Muricidea* (the latter, a virtual admission of ignorance, is a "wastebasket" name for any small muricid otherwise unclassifiable). Most recently Woodring (1959, p. 217) has placed the two American species in the subgenus *Dallimurex* but, as noted above, that name is considered a synonym of *Paziella* and it does not seem applicable to these forms with winged varices.

*PANAMUREX*: This subgenus was erected by Woodring (1959, p. 217) for those species with strong spiral sculpture, strong elongate denticles or ridges on the interior of the outer lip, and elongate denticles on the basal part of the inner lip. He included only the type species and *P. fusinoides* from the Chipola Formation, with *P. laccopoia* included in the synonymy of *P. fusinoides*. The other species here referred to *Panamurex* were either not considered or were otherwise assigned. All of the fossil species, with one exception, are known from the New World. That one exception is an unrecognized species from the Oligocene of Gaas, France, which in appearance is very close to *Panamurex lychnia* (Gardner) from the Chipola Formation. This European species was originally named *Fusus turbinelloides* by Grateloup (1833, Actes Soc. Linn. Bordeaux, v. 6, no. 32, p. 42), who subsequently changed it (without explanation) to *Turbinella muricina* in the *Atlas* to the *Conchyliologie Fossile du Bassin de l'Adour* (? 1847, Turbinelles, pl. 3, fig. 18). Grateloup's illustration is not immediately recognizable but with a specimen in hand it can readily be identified as a *Panamurex*. This same species is the "*Hexaplex* (*Paziella*) *corniculatus* Vergneau" of Glibert, 1963, Mém. Inst. Roy. Sci. Nat. Belg., (Ser. 2), fasc. 74, p. 8. This name remains nude, appearing only in an unpublished thesis, however Dr. Glibert kindly provided the writer with a photograph of the specimen. There may be other species of European *Panamurex* similarly "lost" in the literature.

The oldest species of *Panamurex* in the New World is *P. macneili* (new name for *Murex simplex* Aldrich *non* Philippi), from the Oligocene of Mississippi. There are numerous species in the Miocene of the entire Caribbean and Florida area. The line was thought by Woodring to be extinct but the Caribbean species here named *P.* (*P.*) *velero* Vokes, n. sp., is certainly to be referred to this group. In addition, a specimen of "*Murex*" *carnicolor* Clench and Pérez Farfante, taken by the U. S. Fish and Wildlife M/V *Oregon* (figured here, pl. 6, fig. 6), shows that species to have the characteristic denticulations on both inner and outer

lip. Although this species was previously assigned to *Murexsul* by Clench and Pérez Farfante (1945, p. 48) it seems to be more closely allied with *Panamurex*. The resemblance between *P. lychnia* and *P. carnicolor* is too striking to be ignored. Today *P. carnicolor* is a deep-water species, the most shallow occurrence known is that of the figured specimen, which is 50-60 fathoms.

With the possible exception of *P. lychnia*, which may have been a deeper water form like *P. carnicolor*, the fossils suggest an ecologic preference for a relatively shallow-water habitation with a fine silty bottom. The beds of the Chipola Formation of northern Florida abound with specimens of four species of *Panamurex*. The majority of the specimens are found in the more silty western exposures of the formation along Ten Mile Creek but *P. lychnia* and *P. mauryae* are more abundant in the calcaranite of the Chipola River and Farley Creek. A few specimens of all four species are found at almost any Chipola locality. The other species of *Panamurex* occur in similar silty strata such as the Jackson Bluff, Agueguexquite and Gatun formations.

In a recent work by McLean and Emerson (in press) it has been suggested that the genus *Calotrophon* should be placed in the Muricinae due to similarities of radula and operculum, and this writer must agree with the placement. These authors observed that the shells of *Calotrophon* have a peculiar chalky outer layer comparable to that so well developed in the genus *Aspella* and its subgenera *Dermomurex* and *Takia*. This same chalky layer is seen in *Panamurex* and it seems not unlikely that the *Calotrophon* line was derived from a *Panamurex*-like ancestor.

In an earlier work the writer described a new species "*Murex* (*Panamurex*)" *gilletteorum* (Vokes, 1963, p. 160). At the time the species was compared to "*Murex* (*Panamurex*)" *laccapoia* and "*M.* (*P.*)" *clarksvillensis* and it was noted that the new species differed in lacking the denticles on the inner lip, characteristic of true *Panamurex*. It is now thought that *gilletteorum* is better referred to the genus *Aspella* (*Takia*) but the relationship between these two groups appears to be closer than it was once held to be. Radular work by Radwin and D'Attilio of the San Diego Natural History Museum (largely unpublished, *in litt.*) shows the *Aspella* group to be more closely related to the Muricinae than to the Trophoninae and the writer now feels that *Panamurex*, *Takia*, and *Calotrophon* are all fairly closely related and should all be placed in the subfamily Muricinae.

This same distinctive chalky layer is also seen in the species of *Poirieria* and *Paziella* to a lesser degree, as well as in *Favartia*, and some species of *Trophon* and *Typhis*. In itself it does not seem to be a valid distinction for subfamiliar separation but suggests that all the species that do possess this layer do have a certain degree of kinship. However, it is felt that placing them all in the family Muricidae expresses this kinship adequately and there is no justification in placing species that morphologically differ in other respects together solely on the basis of this layer.

## III. Acknowledgments

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## IV. Systematic Descriptions

### Phylum Mollusca

### Class Gastropoda

### Subclass Prosobranchia

### Order Neogastropoda

### Suborder Stenoglossa

### Family Muricidae

### Genus Pterynotus Swainson, 1833

#### Subgenus Pterynotus s.s.

*Pterynotus* Swainson, 1833, Zool. Illus., (Ser. 2) v. 3, expl. to pl. 100.
Type species: *Murex pinnatus* Swainson (= *Purpura alata* Röding), by subsequent designation, Swainson, *ibid.*, pl. 122.

*Pteronotus* Swainson, 1833, Zool. Illus., (Ser. 2) v. 3, pl. 122. Not *Pteronotus* Rafinesque, 1815, Mamm.

*Marchia* Jousseaume, 1880, Le Naturaliste, Anneé 2, no. 42, p. 335.
Type species: *Murex clavus* Kiener (= *Murex elongatus* Lightfoot), by original designation.

*Timbellus* de Gregorio, 1885, Soc. Malac. Ital., Boll., v. 10, p. 275.
Type species: *Murex latifolius* Bellardi, by subsequent designation, Vokes, 1964.

*Triplex* "Humphrey" Newton, 1891, Edwards Coll. Eocene and Oligocene Moll., p. x, 297.
To be used in place of *Pteronotus* Swainson.

*Pterymurex* Roverto, 1899, Atti Soc. Ligustica, v. 10, p. 105. New name for *Pteronotus* Swainson.

#### Pterynotus (Pterynotus) matthewsensis (Aldrich)

Plate 1, figs. 1a, 1b

*Murex matthewsensis* Aldrich, 1886, Alabama Geol. Surv., Bull. 1, pt. 1, p. 18, 59, pl. 3, fig. 15.

*Murex matthewsensis* Aldrich. de Gregorio, 1890, Ann. Géol. Paléontologie, livr. 7, p. 94, pl. 7, fig. 27 (after Aldrich, 1886).

*Murex* (*Pteronotus*) *matthewsoni* [*sic*] Aldrich. Dall, 1890, Wagner Free Inst. Sci., Trans., v. 3, pt. 1, p. 142.

*Murex* (*Pteronotus*) *matthewsensis* Aldrich. Harris, 1896, Bulls. Amer. Paleontology, v. 1, no. 4, p. 215, pl. 20, fig. 2.

*Murex matthewsensis* Aldrich. Wrigley, 1930, Malac. Soc. London, Proc., v. 19, p. 96.

*Murex* (*Pteropurpura*) *matthewsensis* Aldrich. Palmer *in* Harris and Palmer, 1947, Bulls. Amer. Paleontology, v. 30, no. 117, p. 344.

*Murex* (*Pteronotus*) *matthewsensis* Aldrich. Brann and Kent, 1960, Bulls. Amer. Paleontology, v. 40, no. 184, p. 571.

[*Pterynotus* (*Pterynotus*)] *matthewsensis* (Aldrich). E. H. Vokes, 1964, Malacologia, v. 2, no. 1, p. 15.

*Pterynotus matthewsensis* (Aldrich). Palmer and Brann, 1966, Bulls. Amer. Paleontology, v. 48, no. 218, p. 864.

*Diagnosis*: "Shell triangular, whorls probably four; angular, smooth between the varices; varices three, longitudinal, prominent; spines of the body whorl elongated and curved upward, the one at the angle of the aperture nearly closed; body whorl angulated on upper part, the other whorls rounded; aperture ovate, outer lip thick with a foliation at the junction with the body whorl running from the spine to the beak; inner lip smooth with a slight lamina; beak short; canal rather wide." (Aldrich, 1886)

Dimensions of holotype: height (incomplete) 13 mm, diameter 8.2 mm.

Holotype: USNM 638751.

Type locality: Matthews Landing, Alabama River, Wilcox County, Alabama.

*Occurrence*: Matthews Landing Marl, Alabama; Paleocene.

*Figured specimen*: PRI 24532; height 17.3 mm, diameter 7 mm; locality, Matthews Landing, Alabama River, Wilcox County, Alabama (specimen figured by Harris, 1896, pl. 20, fig. 2). Other occurrences: TU locality no. 325.

*Discussion*: *P. matthewsensis* is one of the oldest known forms of Muricinae. This species, together with *Poirieria* (*Paziella*) *harrisi* Vokes (new name for *Murex morulus* Conrad *non* Schröter), is found in the Matthews Landing Marl member of the Porters Creek Formation of upper Paleocene age. It is a small species, the specimen figured by Harris and refigured here is the largest specimen seen. To the writer's knowledge there are but three specimens known in collections, but this is probably due to the small size rather than to any special rarity on the part of the fossil.

#### Pterynotus (Pterynotus) stenzeli E. H. Vokes, n. sp.

Plate 1, figs. 5a, 5b

*Diagnosis*: Nucleus of three and one-half smooth, conical whorls; seven post-nuclear whorls in adult. Axial ornamentation of six or seven small varices on first two post-nuclear whorls, becoming three varices and three strong intervarical nodes on each of the succeeding whorls. Varices thin and bladelike, forming an almost straight line up the spire. Spiral ornamentation of faint ribs, five on the body whorl.

Where these spiral ribs cross the varices small folds formed, recurving slightly back from the apertural face. Aperture oval, with a marked infolding at the shoulder, forming a spine; however, apertural lip is not channeled into the spine as in *Pterochelus*. Outer lip with six denticles corresponding to interspaces between spiral ribs; columellar lip smooth. Siphonal canal moderately long, open, slightly recurved at distal end.

Dimensions of holotype: height 19 mm, diameter 11.3 mm.

Holotype: Texas Bureau of Economic Geology no. 36637.

Type locality: TBEG no. 173-T-19, four miles west of Chireno; hill on San Augustine road (Texas Highway 21), Nacogdoches County, Texas (= TU 993).

*Occurrence*: Weches Formation, Texas; early middle Eocene.

*Figured specimen*: TBEG 36637 (holotype). Other occurrences: TU locality no. 993 and TBEG locality no. 113-T-17, Wheeler Springs School, Houston County, Texas.

*Discussion*: This new species from the Weches Formation of eastern Texas is not rare in the vicinity of the type locality as there are 22 specimens in the type lot, from two localities. In addition, there are four specimens in the collections of the Philadelphia Academy of Natural Sciences (nos. 9419 and 9738) from near Jewett, Leon County, and from near Alto, Cherokee County, Texas. In all, the line of occurrence stretches for over 100 miles in a slightly arched line trending almost due east-west.

*P. stenzeli* differs from the other Eocene species of *Pterynotus* in having stronger spiral ornamentation and by having the labral lip folding into the shoulder spine. In this latter trait it resembles the Paleocene *P. matthewsensis* but has much stronger spiral ornamentation. The species attains a larger size than is indicated by the holotype, one unfigured paratype measures 30 mm in height.

The writer is pleased to name this new species in honor of Dr. Henryk B. Stenzel, who collected much of the type material.

## Pterynotus (Pterynotus) sabinola (Palmer)

Plate 1, figs. 2a, 2b

*Murex veatchi* Palmer, 1937, Bulls. Amer. Paleontology, v. 7, no. 32, p. 266, pl. 36, figs. 7, 11, 12. *Non Murex veatchi* Maury, 1910.

*Murex sabinola* Palmer *in* Brann and Kent, 1960, Bulls. Amer. Paleontology, v. 40, no. 184, p. 572, 989. New name for *M. veatchi* Palmer *non* Maury.

*Murex veatchi* Palmer. Brann and Kent, 1960, Bulls. Amer. Paleontology, v. 40, no. 184, p. 573.

*Murex sabinola* Palmer. Palmer and Brann, 1966, Bulls. Amer. Paleontology, v. 48, no. 218, p. 783.

*Diagnosis*: "Shell elongate; spire elevated; post-nuclear whorls four; anterior canal long; varix sculpture trilobate, with the varices wide and flaring; midway between the varices is a longitudinal fold which is subdued forming a large node on each whorl; the longitudinal sculpture is crossed by spiral lines, widely spaced on the flared varices; on a fragment of an old individual intermediate ribs are developed on the labrum flange and the primary ribs are large and coarse; labrum crenate on the inner margin." (Palmer, 1937)

Dimensions of holotype: height 16 mm, diameter 9 mm.

Holotype: PRI 3012.

Type locality: Sabine River (opposite SE ¼ Sec. 35, T5N, R13W), Sabine County, Texas.

*Occurrence*: Stone City Beds, Texas; Cook Mountain Formation, Texas and Louisiana; early middle Eocene.

*Figured specimen*: PRI 3012 (holotype).

*Discussion*: This species is based on an immature specimen for it has only four post-nuclear whorls; an adult specimen in the collections of the Texas Bureau of Economic Geology has seven post-nuclear whorls and measures 24 mm in height. Nevertheless, the general aspect of the type is that of a mature individual and there is little difference between it and the full grown specimen. The species is known only from a small area near the Sabine River. The type locality (Veatch's locality 21) is in the Stone City Beds of early middle Eocene age. Paratype material is also known from the slightly younger Cook Mountain Formation at Columbus, on the Louisiana side of the Sabine River near the type locality. The above-mentioned Texas Bureau specimen comes from the Wheelock Member of the Cook Mountain Formation at Harper's Chapel, Texas, also near the type locality. Regrettably these few specimens of *P. sabinola* are probably all that will ever be known, for the famous localities along the Sabine River are now beneath the waters of an artificial lake created by a dam at Toledo Bend, just downstream from Columbus. (What price progress!). There is one faint ray of hope, however. In the collections of the Academy of Natural

Sciences of Philadelphia there is a single specimen (no. 9204) from the Cook Mountain Formation at Alabama Bluff, on the Trinity River, Houston County, Texas. Perhaps other localities will be discovered to replace the Sabine River section.

*P. sabinola* closely resembles *P. tricarinatus* (Lamarck) from the middle Eocene of the Paris Basin. It differs from the European species principally in having stronger denticles on the outer lip and less marked spiral ornamentation. *P. sabinola* has only five to seven faint spiral ribs and *P. tricarinatus* has about nine strong spiral lines, even on specimens of the same small size as the holotype of *P. sabinola*.

## Pterynotus (Pterynotus) weisbordi (Palmer)

Plate 1, figs. 3a, 3b

*Murex* (*Pteropurpura*) *weisbordi* Palmer *in* Harris and Palmer, 1947, Bulls. Amer. Paleontology, v. 30, no. 117, p. 343, pl. 45, figs. 19–21.

*Murex* (*Pteropurpura*) *weisbordi* Palmer. Brann and Kent, 1960, Bulls. Amer. Paleontology, v. 40, no. 184, p. 574.

*Pterynotus weisbordi* (Palmer). Palmer and Brann, 1966, Bulls. Amer. Paleontology, v. 48, no. 218, p. 865.

*Diagnosis*: "Shell slender, spire elevated; nuclear whorls worn; postnuclear whorls, probably first and second, have longitudinal folds extending the length of the whorl; on the third whorl, three of the longitudinal folds become continuous from whorl to whorl forming varices of a trivaricate pattern. The remaining intervening longitudinal folds of the third whorl develop into blunt nodes between the varices on the whorls. The varices are flangelike. The surface of the shell is covered with fine spiral ribs with wide interspaces. Canal is long; outer lip crenulated; inner lip smooth." (Palmer, 1947)

Dimensions of holotype: height 33.5 mm, diameter 15 mm.

Holotype: PRI 4657.

Type locality: Montgomery Landing, Red River, Grant Parish, Louisiana (= TU 99).

*Occurrence*: Moodys Branch Marl, Louisiana; upper Eocene.

*Figured specimen*: PRI 4657 (holotype).

*Discussion*: *P. weisbordi* is known only from the type locality and the vicinity of Gibson Landing, on the Ouachita River, Caldwell Parish, Louisiana. Palmer stated that it differed from its nearest relative, *P. sabinola*, in having the spire whorls larger and the spiral ribs finer in *P. weisbordi*. *P. weisbordi* is ornamented by numerous fine spiral lines; *P. sabinola* has but five to seven faint, widely spaced spiral ribs. This species bears an even stronger resemblance to *P. tripteroides* (Lamarck) from the middle and upper Eocene beds of the Paris basin. It differs from that species in having a less appressed suture and finer spiral ornamentation.

## Pterynotus (Pterynotus) burnsii (Aldrich)

Plate 2, figs. 1a, 1b

Not *Murex* (*Chicoreus*?) *burnsii* Whitfield. Dall, 1890, Wagner Free Inst. Sci., Trans., v. 3, pt. 1, p. 141 (nude name).

*Murex* (*Pteronotus*) *burnsii* Aldrich, 1894 (January), Nautilus, v. 7, p. 98, pl. 4, figs. 4, 4a.

Not *Murex shilohensis* var. *burnsi* Whitfield, 1894 (post-March), U. S. Geol. Surv., Mon. 24, pt. 3, p. 98, pl. 17, fig. 2 (= *Murexiella macgintyi faceta*).

*Murex* (*Pteronotus*) *grandispinosa* Aldrich, 1895, Bulls. Amer. Paleontology, v. 1, no. 2, p. 66. Unnecessary new name for *M. burnsii* Aldrich.

Not *Murex burnsii* Dall. Dall, 1903, Wagner Free Inst. Sci., Trans., v. 3, pt. 6, p. 1566 (= *Panamurex heilprini*).

Not *Murex* (*Chicoreus* ?) *burnsii* Whitfield [Dall]. Schuchert, *et al.*, 1905, U. S. Natl. Mus., Bull. 53, p. 419 (= *Panamurex heilprini*)

*Murex* (*Pteronotus*) *burnsii* Aldrich. Schuchert, *et al.*, 1905, U. S. Natl. Mus., Bull. 53, p. 419.

Not *Murex shilohensis burnsi* Whitfield. Schuchert, *et al.*, 1905, U. S. Natl. Mus., Bull. 53, p. 420 (= *Murexiella macgintyi faceta*).

Not *Chicoreus burnsii* (Whitfield). Dall, 1915, U. S. Natl. Mus., Bull. 90, p. 75 (= *Panamurex heilprini* and *Murexiella macgintyi faceta*).

Not *Murex* (*Chicoreus*) aff. *burnsii* Whitfield. Gardner and Aldrich, 1919, Acad. Nat. Sci. Phila., Proc., v. 71, p. 18 (= *Murexiella macgintyi faceta*).

Not *Muricidea burnsii* (Whitfield). Richards and Harbison, 1942, Acad. Nat. Sci. Phila., Proc., v. 94, p. 212, pl. 19, fig. 10 (= *Murexiella macgintyi faceta*).

*Murex* (*Pteronotus*) *burnsii* Aldrich. E. H. Vokes, 1963, Tulane Stud. Geol., v. 1, no. 3, p. 1, p. 158.

*Diagnosis*: "Shell large, with three foliated varices, whorls nine. Nucleus pointed, smooth; whorls convex, appressed at suture, whorls following the nucleus have two ribs on centre, each rib bearing a node which is equidistant

from the foliations; three continuous fin-like varices continued from apex, which revolve in decending, edges of varices dentate. Body whorl with about thirteen distant spiral raised ribs, the two on the periphery bearing a node each between the foliations. Aperture elongate-oval. Outer lip having internally seven plications, inner lip smooth; canal rather long, almost closed posteriorly, widening anteriorly, and bent upwards. Canal of preceding aperture persistent." (Aldrich, 1894)

Dimensions of holotype: height 67.5 mm, diameter 33 mm.

Holotype: USNM 135155.

Type locality: Carson's Creek, 1½ to 2 miles west of Red Bluff (Chickasawhay River), Wayne County, Mississippi.

*Occurrence*: Red Bluff Clay, Mississippi; lower Oligocene.

*Figured specimen*: USNM 135155 (holotype).

*Discussion*: *Pterynotus burnsii* is a direct descendant of the middle and upper Eocene Tethyan species *P. tripteroides* (Lamarck). This latter species has not been reported from the New World but in the Tulane collections there is a single specimen from the Ocala Limestone (TU 449) that is probably referable to *P. tripteroides*, however it is too poorly preserved for one to be certain. *P. burnsii* differs from *P. tripteroides* in having coarser spiral ornamentation and fewer denticles within the outer lip. The type, and only specimen, of *P. burnsii* is also larger than any specimens seen of *P. tripteroides*, which usually measures a maximum of approximately 55 mm.

*P. burnsii* is involved in a nomenclatorial tangle due to an overlong delay in publication. In 1889 Whitfield submitted a monograph on the fauna of the Miocene of New Jersey in which he described a species as "*Murex shilohensis* var. *burnsi*." In 1890, Dall (p. 141) noted that "the truncated specimen upon which Prof. Whitfield has founded his variety *Burnsii*, belongs, in my opinion, to a different species and subgenus [than *Murex shilohensis*]." But he had seen only Whitfield's manuscript, for the work was not finally published until after March, 1894 (*fide* advertisement, p. vi). In the meantime Aldrich had named his *Murex burnsii* after the same man, Frank Burns of the U. S. National Museum, in the January, 1894, issue of "Nautilus." The following year Aldrich (1895, p. 66) noted that Dall had made Whitfield's "variety *burnsi*" into a distinct species and hence he proposed *Murex* (*Pteronotus*) *grandispinosa* as a replacement name for his *Murex burnsii*. Dall's usage of *M. burnsii* Whitfield can only be construed as a nude name and so this change was unnecessary on Aldrich's part.

## Pterynotus (Pterynotus) propeposti (Mansfield)

Plate 1, figs. 4a, 4b

*Purpura* (*Pteropurpura*) *propeposti* Mansfield, 1937, Florida Geol. Surv., Bull. 15, p. 51, 131, pl. 5, figs. 8, 10.

*Diagnosis*: "Shell elongate, with a rather high, turreted spire and long canal. Nucleus poorly preserved. Axial sculpture of three strong, sharp, continuous, marginally broken varices which are spinose at the periphery of the spire whorls and at the shoulder of the body whorl. A rather strong rib lies midway between the varices and an elongate nodule is on either side of this nodule [*sic*]. Body whorl and canal sculptured with about 17 rather strong primaries usually alternating with one secondary spiral. The margin of the outer lip probably is broken away; inner margin of outer lip with 7 strong, rounded entering denticles. Inner lip provided with a callus; canal long and deflected anteriorly; aperture ovate; anterior siphonal canal nearly closed." (Mansfield, 1937)

Dimensions of holotype: height 43 mm, diameter 20 mm.

Holotype: USNM 49545.

Type locality: Blackwater Creek, at crossing of Seaboard Airline Railroad, Hillsborough County, Florida.

*Occurrence*: Suwannee Limestone, Florida; upper Oligocene.

*Figured specimen*: USNM 49545 (holotype).

*Discussion*: This species was attributed with a query to the upper Oligocene Suwannee Limestone by Mansfield, for he believed that at the type locality both the Suwannee and the younger Tampa Limestone occur. As the fossils were in a spoil bank, it would be difficult to ascertain from which formation the specimen came. However, Druid Wilson, of the United States Geological Survey (*in litt.*), advises that it is doubtful if there is any Tampa Limestone at Blackwater Creek. It is simply the long exposed, deeply weathered Suwannee Limestone that carries the silicified fossils. All species that have been identified from this locality are of Oligocene age.

Mansfield (1937, p. 131) suggested that *P. propeposti* might prove to be just a variety of the younger *P. postii* if better specimens

were collected. But the two forms are very different, *P. propeposti* is much more elongate and the siphonal canal is greatly extended in comparison with *P. postii.*

### Pterynotus (Pterynotus) rufirupicolus (Dall)

*Murex rufirupicolus* Dall, 1916, U. S. Natl. Mus., Proc., v. 51, no. 2162, p. 506, pl. 86, fig. 8.

*Diagnosis*: "Specimen represented by an internal cast with a slightly defective apex; fusiform with over four whorls, a long straight canal, a rounded aperture, the outer lip expanded, thickened, crenulate, with a prominent guttered spine at the shoulder, a large dentiform callosity internally just in front of the suture, and six prominent internal lirations diminishing anteriorly, in front of the groove at the shoulder. There appear to have been two feeble varices or thickenings visible on the internal cast on each of the antecedent whorls, and an expansion of the outer lip continued some distance down on the right margin of the canal." (Dall, 1916)

Dimensions of holotype: height 42 mm, diameter 19 mm.

Holotype: USNM 166725.

Type locality: Red Bluff, west bank of Flint River, seven miles above Bainbridge, Decatur County, Georgia.

*Occurrence*: Flint River Formation, Georgia; upper Oligocene.

*Discussion*: This species was based on an internal mold and it is impossible to determine exactly what species it is. However, it bears a strong resemblance to the contemporary *P. propeposti* Mansfield. As that species is based upon a good type specimen it seems best to treat "*Murex*" *rufirupicolus* as a *nomen dubium* rather than to replace the later, but more certain taxon of Mansfield.

### Pterynotus (Pterynotus) postii (Dall)

Plate 2, figs. 2a, 2b

*Pteropurpura postii* Dall, 1896, U. S. Natl. Mus., Proc., v. 18, no. 1035, p. 44; Dall, 1900, Wagner Free Inst. Sci., Trans., v. 3, pt. 5, pl. 43, fig. 7.

*Purpura* (*Pteropurpura*) *posti* Dall. Dall, 1915, U. S. Natl. Mus., Bull. 90, p. 76, pl. 7, fig. 9.

*Murex* (*Pteropurpura*) *posti* (Dall). Dall, 1903, Wagner Free Inst. Sci., Trans., v. 3, pt. 6, p. 1566.

*Purpura* (*Pteropurpura*) *posti* (Dall). Mansfield, 1937, Florida Geol. Surv., Bull. 15, p. 131.

*Pteropurpura postii* Dall. Gardner, 1947, U. S. Geol. Surv. Prof. Paper 142-H, p. 525.

*Diagnosis*: "Shell of moderate size, with five whorls, beside the (decollate) nucleus, with three sharp continuous varices extending down the spire and a single prominent intervarical nodule on the interspaces of the whorls; the last varix broader than any of the others, with a posterior angle, the front sculptured with five crenulate imbricated lamellae, the back smooth, except for the ends of the spiral ribbing; spiral sculpture of (about 15 on the last whorl) low spiral ribs most prominent on the intervarical nodules, the rather wide interspaces finely spirally striate; aperture small, subovate, the outer lip with about seven strong teeth; the body with a thin smooth callus; suture appressed, obscure; canal open, narrow, not quite as long as the aperture; on the siphonal fasciole a single projecting remnant of an earlier canal is visible." (Dall, 1896)

Dimensions of holotype: height 38 mm, diameter 21 mm.

Holotype: USNM 130349.

Type locality: Ballast Point, Tampa Bay, Hillsborough County, Florida.

*Occurrence*: Tampa Limestone, Florida: lower Miocene.

*Figured specimen*: USNM 130349 (holotype).

*Discussion*: *P. postii* is known from but two examples from the type locality. Although Dall referred this species to the genus *Pteropurpura*, that name is inapplicable because, as was discussed previously, that genus is correctly assigned to the subfamily Ocenebrinae, characterized by a completely sealed-over siphonal canal.

### Pterynotus (Pterynotus) hoerlei E. H. Vokes, n. sp.

Plate 2, figs. 3a, 3b

*Diagnosis*: Nucleus of one and one-half smooth, rounded whorls, ending at a small varix; seven post-nuclear whorls in the adult. Ornamentation on first post-nuclear whorl consisting of nine small varices, no spiral ornamentation. Varices reduced to six on second post-nuclear whorl and to three on third and succeeding whorls. Between each pair of varices one low axial node; intervarical areas unornamented. Spiral ornamentation visible only on the varices where about nine faint spiral ribs are developed on the body whorl. Varices simple, flaring, crenulated by the spiral ribs; each one joined to the corresponding varix of the previous whorl to form a continuous slightly curved line up the spire. Suture greatly appressed. Aperture oval; inner lip smooth, outer lip bearing six strong denticles, which reflect the position of the external ribbing. Canal moderate in length, open, recurved, bearing a lamel-

lar extension of the varices almost its entire length.

Dimension of holotype: height 59 mm, diameter 29.5 mm.

Holotype: USNM 645616.

Type locality: TU 547, west bank of Chipola River (SW ¼ Sec. 29, TIN, R9W), Calhoun County, Florida.

*Occurrence*: Chipola Formation, Florida; (?) late lower Miocene.

*Figured specimen*: USNM 645616 (holotype). Other occurrences: TU locality no. 555.

*Discussion*: This rare species is based on four specimens known only from the vicinity of the type locality. It is closely related to *P. postii* from the older Tampa Limestone but has a more elongate, smoother shell. In general outline it more nearly resembles the Oligocene *P. burnsii* (Aldrich) but is also smoother than that species. Likewise, it is closely related to the Recent Indo-Pacific species *P. phyllopterus* (Lamarck) of which *P. rubridentatus* (Reeve) is a synonym. In the Recent form the denticles on the outer lip are tipped with a beautiful rose-pink, hence Reeve's name, making this one of the more strikingly beautiful muricine species. The entire line extends back to the middle Eocene species *P. tripteroides* (Lamarck) in a remarkably persistent shell type.

The writer takes pleasure in naming this exquisite new species in honor of Mr. Robert C. Hoerle, of West Palm Beach, Florida, who cheerfully parted with the type specimen only seconds after he discovered it.

### Pterynotus (Pterynotus) havanensis
E. H. Vokes, *nom. nov.*

Plate 3, figs. 1a, 1b

*Murex* (*Pteronotus*) *tristichus* Dall, 1889, Harvard Mus. Comp. Zool., Bull., v. 18, p. 202, pl. 15, fig. 3; Dall, 1889, U. S. Natl. Mus., Bull. 37, p. 120, pl. 15, fig. 3. *Non Murex tristichus* Beyrich, 1854.

*Pteropurpura tristica* (Dall). Dall, 1927, U. S. Natl. Mus., Proc., v. 70, no. 2667, p. 58.

*Murex* (*Pterynotus*) *tristichus* Dall. Clench and Pérez Farfante, 1945, Johnsonia, v. 1, no. 17, p. 36, pl. 20, figs. 1-4.

[*Pterynotus* (*Pterynotus*)] *tristichus* (Dall). E. H. Vokes, 1964, Malacologia, v. 2, no. 1, p. 15.

*Diagnosis*: "Shell pure white, thin, polished, delicate, with six rather loosely coiled, rounded whorls; body more slender than in the last species [*P. phaneus*], sutures much deeper and not appressed. Nucleus large, loosely coiled, glassy, white; varices making about one quarter of a revolution around the spire, very thin, edges dentate, prolonged on the shoulder of the whorls into a long pinna with a flat central rib; below there are three other less prominent ribs, which project at the edge of the varix on the last whorl; there is no transverse sculpture except incremental lines, nor any inter-varical ribs; the spiral sculpture is obscure and very faint, except the ribs on the varices; aperture small, pear-shaped; canal open, rather long, bent to the right, the canal belonging to the preceding varix, behind it, persistent and bent to the left." (Dall, 1889)

Dimensions of holotype: height 15.5 mm, diameter 10 mm.

Holotype: Harvard MCZ 7308.

Type locality: *Blake* Station 51, off Havana, Cuba, in 400 fathoms.

*Occurrence*: Recent only.

*Figured specimen*: MCZ 7308 (holotype).

*Discussion*: As with all of the Recent western Atlantic *Pterynotus* the species named *Murex tristichus* by Dall is very rare. There are but three adult specimens known. Dall (1889, p. 202) stated that the type came from a depth of 243-450 fathoms, *Blake* Station 51, off Havana, and the paratype from Station 5 at a depth of 152-229 fathoms. But the labels with the specimens state that the type came from a depth of 400 fathoms and the paratype from the same station at a depth of 450 fathoms. Dall later (1927, p. 58) noted that the *Albatross* had taken one adult and many juvenile shells off the southeastern United States, but no depths were given.

The name *Murex tristichus* of Dall is preoccupied by *Murex tristichus* used by Beyrich for a German Oligocene fossil. It is ironic but the two species are actually very similar in form, each taking their name from the three lines of varices ascending the spire (*tri - stichos*).

### Pterynotus (Pterynotus) bushae
E. H. Vokes, *nom. nov.*

Plate 3, figs. 2a, 2b

*Murex* (*Pteronotus*) *pygmaeus* Bush, 1893, Harvard Mus. Comp. Zool., Bull., v. 23, p. 213, pl. 1, figs. 3, 4. *Non Muricites pygmäus* Schlotheim, 1820 (*vide* ICZN Code, Art. 56b).

*Murex* (*Pterynotus*) *pygmaeus* Bush. Clench and Pérez Farfante, 1945, Johnsonia, v. 1, no. 17, p. 36, pl. 20, figs. 7, 8.

*Diagnosis*: "Shell small, fusiform, rather thin, of a light yellow color. Whorls six, evenly and moderately rounded, ornamented with three high, thin foliaceous varices and covered with coarse revolving threads and microscopic striae.

Aperture nearly round, with a long, curved, tubular canal, and a smooth, lustrous interior. Outer lip with a slightly thickened edge, descending a little obliquely from the suture, forming a slight obtuse posterior angle, below which it is somewhat flaring and curves well round to the base of the canal, where there is another slight angle, then curves gradually outward to the end of the canal. Inner lip formed by a rather narrow, thin, lustrous layer of enamel closely adhering to the body whorl to just above the base of the canal, where it becomes detached and twists forward and over to meet the outer lip, nearly or quite closing the canal its entire length. There is a tube corresponding to a former canal on the left of the present one for about half its length, which projects strongly outward at the end. Operculum thin, horny, amber-colored. Suture distinct, slightly channelled. Varices three, equally spaced, high, very thin, with an irregular slightly notched edge, the last one formed a little before the edge of the outer lip. Each stands a little in front of the corresponding one above, rises above the suture, laps a little on to the preceding whorl, then reaches high above with a re-entrant curve, the greatest height being in a line with the posterior angle of the aperture. When dry, the surface on the back of these and between them is without lustre, and is covered with microscopic revolving striae crossed by inconspicuous lines of growth. There are also a few broad, widely separated, rather indistinct revolving threads, which are most apparent on the varices. These number about eight on the last varix, but the two or three lowest ones are almost imperceptible. The surface on the front of the varices is very lustrous, covered with the very thin, irregular edges of the several layers of growth; the upper revolving threads appear as broad shallow grooves. Nucleus large, of two smooth lustrous whorls, the apical one prominent and decidedly upturned." (Bush, 1893)

Dimensions of holotype: height 16 mm, diameter 8.5 mm.

Holotype: Harvard MCZ 6918.

Type locality: *Blake* Station 319, off Charleston, South Carolina, in 262 fathoms.

*Occurrence*: Recent only.

*Figured specimen*: MCZ 6918 (holotype).

*Discussion*: The species named by Bush as *Murex pygmaeus* is based on a single specimen taken from 262 fathoms off Charleston, South Carolina. It has not been reported by subsequent workers and nothing can be added to the original data. *Murex pygmaeus* is preoccupied by the name *Muricites pygmäus* Schlotheim, for the International Code of Zoological Nomenclature (Art. 56b) states: "A genus-group name formed for use in paleontology by substituting *-ites* . . . for the original termination of a generic name, and applied only to fossils, enters into homonymy." Although not a "German word" (Art. 32(c)i), it was treated as such by Schlotheim and thus should be emended to *pygmaeus*, the correct Latin spelling.

## Pterynotus (Pterynotus) phaneus (Dall)

Plate 3, figs. 3a, 3b

*Murex* (*Pteronotus*) *phaneus* Dall, 1889, Harvard Mus. Comp. Zool., Bull., v. 18, p. 201; Dall, 1889, U. S. Natl. Mus., Bull. 37, p. 120, pl. 42, fig. 1; Dall, 1890, U. S. Natl. Mus., Proc., v. 12, no. 772, p. 330, pl. 11, fig. 1.

*Murex* (*Pterynotus*) *phaneus* Dall. Clench and Pérez Farfante, 1945, Johnsonia, v. 1, no. 17, p. 37.

*Diagnosis*: "Shell ashy white, elongated, thin, six-whorled. Nucleus translucent, smooth, polished, of about one and a half whorls; whorls slightly convex, appressed to the suture behind them, connected by three continuous fin-like varices which in descending the spire make about half a revolution around it; these varices on the upper whorls were extended backward into a little wing-like point with dentate edges; on the last whorl the lines of growth indicate that the thin margin was rounded, parallel with the whorl. Transverse sculpture of fine growth-lines, and on the last two whorls at the periphery three short little narrow pinched-up riblets between the varices; spiral sculpture of fine rather faint striae and wider undulations, hardly visible except on the varices; of these there are nine or ten on the last varix. Aperture elongate-oval, internally white, thickened, smooth; canal rather long, open, bent back." (Dall, 1889)

Dimensions of holotype: height 17 mm, diameter 7 mm.

Holotype: USNM 93256.

Type locality: *Albatross* Station 2662, off St. Augustine, Florida, in 434 fathoms.

*Occurrence*: Recent only.

*Figured specimen*: USNM 93256 (holotype).

*Discussion*: Much more material is needed before the western Atlantic species of *Pterynotus* are fully understood. Each of the three known species is based on one or two specimens, and no idea of variation can be determined. *P. phaneus* closely resembles *P. havanensis* but differs in the presence of the three intervarical nodes seen in *P. phaneus*. *P. havanensis* is completely smooth between the varices. Whether this is within the range of variation is not known but the two type specimens are approximately the same size so that age is not a consideration. *P. bushae*

even more closely resembles *P. phaneus* but also is smooth between the varices.

There is another species in the western Atlantic that was referred to *Pterynotus* by Clench and Pérez Farfante (1945, p. 38). This is "*Murex*" *abyssicola* Crosse, 1865, which seems from close examination of the original description and illustration to be a juvenile specimen of *Aspella* (*Dermomurex*). It will be covered with that group.

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Subgenus PTEROCHELUS Jousseaume, 1880

*Pterochelus* JOUSSEAUME, 1880, Le Naturaliste, Année 2, no. 42, p. 335.
Type species: *Murex acanthopterus* Lamarck, by original designation.
*Alipurpura* "Bayle MS" FISCHER, 1884, Man. de Conchyl., p. 641.
Type species: *Murex acanthopterus* Lamarck, by original designation.

## PTERYNOTUS (PTEROCHELUS) ANGELUS (Aldrich)

Plate 3, figs. 5a, 5b

*Murex* (*Pteronotus*) *angelus* ALDRICH, 1886, Cincinnati Soc. Nat. Hist., Jour., v. 8, no. 2, p. 145, pl. 2, fig. 2; ALDRICH, 1886, Alabama Geol. Surv., Bull. 1, pt. 1, p. 18, pl. 2, fig. 2.
*Murex angelus* Aldrich. VON KOENEN, 1889, Geol. Specialkarte Preuss. Thüring. Staat., Abh., v. 10, no. 1, p. 52.
*Murex* (*Pteronotus*) *angelus* Aldrich. DALL, 1890, Wagner Free Inst. Sci., Trans., v. 3, pt. 1, p. 142.
*Murex angelus* Aldrich. WRIGLEY, 1930, Malac. Soc. London, Proc., v. 19, p. 97.

*Diagnosis*: "Shell, oblong, with three spinous varices; whorls convex, seven; spire, elevated; surface, rough, showing three or four revolving lines on the body whorl; spines, channeled to the tips, nearly closed, small sub-spines between the larger ones; aperture, oval; outer lip, ridged; inner lip, reflected; canal, long, longer than the aperture, curving outward." (Aldrich, 1886)

Dimensions of holotype: height 26 mm, diameter 14 mm.

Holotype: USNM 644608.

Type locality: Red Bluff, Chickasawhay River, Wayne County, Mississippi.

*Occurrence*: Red Bluff Clay, Mississippi; lower Oligocene.

*Figured specimen*: USNM 644608 (holotype).

*Discussion*: This species from the lower Oligocene beds of Mississippi is closely related to, if indeed not identical with, *P. bispinosus* (J. de C. Sowerby) from the upper Eocene and lower Oligocene of western Europe. This similarity was noted by von Koenen (1889, p. 52, pl. 2, figs. 8-10), who figured specimens from the lower Oligocene of northern Germany at Lattorf and by Wrigley (1930, p. 97, pl. 9, fig. 7), who figured a specimen from the upper Eocene of England. The latter author stated (p. 98) "one strongly suspects that the European and American forms are identical." As far as the writer knows there are but three rather poor specimens of *P. angelus* in collections, all at the USNM, and she hesitates to unite the two forms in synonymy without more material.

## PTERYNOTUS (PTEROCHELUS) ARIOMUS (Clench and Pérez Farfante)

*Murex* (*Pterynotus*) *ariomus* CLENCH and PÉREZ FARFANTE, 1945, Johnsonia, v. 1, no. 17, p. 39, pl. 20, figs. 5, 6.
[*Pterynotus* (*Pterochelus*)] *ariomus* Clench and Pérez Farfante. E. H. VOKES, 1966, Veliger, v. 8, no. 3, p. 165.

*Diagnosis*: "Shell about 25 mm (1 inch) in length, rather solid and non-spinose. Whorls six and one-half and moderately globose. Color a dull white. Spire extended. Suture rather deeply impressed. Aperture oblique and oval, porcellaneous white within. Parietal lip adnate above, free and erect below. Palatal lip non-denticulated below. Siphonal canal broad and short, recurved upward at its distal end. Axial sculpture consists of three low and rather thin, laminated varices with a prominent angle rather than a spine at the shoulder area. The laminations are numerous, quite irregular and rather compact. There is a single knob-like ridge in between the varices. Spiral sculpture consists of numerous and rather fine ribs which turn up to sculpture the back side of the varices. The entire surface of the shell is covered with very small scale-like processes other than on the forward or the front side of the varices. At the suture these scales buttress the whorl above. Nuclear whorls one and one-half, small, rounded, smooth, the first whorl slightly twisted. Postnuclear whorls similar to later whorls. Operculum unguiculate and having an apical nucleus. No periostracum." (Clench and Pérez Farfante, 1945)

Dimensions of holotype: height 24 mm, diameter 12.5 mm.

Holotype: Harvard MCZ 164734.

Type locality: Off Hollywood, Florida, in 50 to 60 fathoms.

*Occurrence*: Recent only.

*Discussion*: The holotype of *P. ariomus* is the sole representative in the western Atlantic of the *Pterochelus* group, which achieved

worldwide distribution in the Eocene. The type specimen was taken in 50 to 60 fathoms and it is surprising that there are no other specimens of the form presently known. The shell looks very much like a small *P. triformis* (Reeve) from Australia, but the fact that it was taken alive would seem to perclude the possibility of artificial transport from Australia to the Gulf of Mexico. A similar situation occurs with *Pterochelus phillipsi* E. H. Vokes, a species described from the California coast. This species is exceedingly close to *P. duffusi* (Iredale) and were it not taken alive the writer would have had grave doubts concerning the locality data. The extreme similarity of all the Recent and fossil forms suggests that these resemblances are due to the ultraconservatism of the group and not to mistaken locality data. In the Pliocene of England there is another species of *Pterochelus*, *P. elegantula* (Harmer), which is very much like *P. ariomus*, and presumably gave rise to it.

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## Subgenus PURPURELLUS Jousseaume, 1880

*Purpurellus* JOUSSEAUME, 1880, Le Naturaliste, Année 2, no. 42, p. 335.
Type species: *Murex gambiensis* Reeve, by original designation.
*Triremis* "Bayle MS" FISCHER, 1884, Man. de Conchyl., p. 641.
Type species: *Murex gambiensis* Reeve, by original designation.

### PTERYNOTUS (PURPURELLUS) REPETITI E. H. Vokes, n. sp.

Plate 3, figs. 4a, 4b

*Diagnosis*: Nature of protoconch and early whorls unknown; probably six post-nuclear whorls in adult. Shell surface completely smooth; suture appressed. Axial ornamentation consisting of three rows of flared varices ascending the spire in an almost straight line; a single knob-like projection in each intervarical area. Spiral ornamentation visible only on abapertural side of varices as very faint ribs, reflecting the stronger ribbing on the varical face; varices composed of multiple layers of shell, folded back from a smooth rim; crenulated by ten to twelve strong folds; at the shoulder an open channel produced but covered over by a down-folded flap of shell material and seen only if specimen is broken. Aperture oval, completely surrounded by a smooth, raised peristome. Siphonal canal long, straight, wide, covered over by a widened portion of the columellar lip, which is cemented to the outer lip; after varix is abandoned the point of juncture with this flap and the outer lip remains as an indentation at the base of the body whorl; distal end of siphonal canal slightly recurved.

Dimensions of holotype: height (incomplete) 53.5 mm [estimated total height 60 mm], diameter 28 mm.

Holotype: USNM 646438.

Type locality: TU 866, marl pit on north side of Webb Creek and east side of unnumbered county highway, Silverdale, Onslow County, North Carolina.

*Occurrence*: "Silverdale Beds," North Carolina; early lower Miocene.

*Figured specimen*: USNM 646438 (holotype).

*Discussion*: This new species is the earliest known occurrence of the subgenus *Purpurellus*. It is found at Silverdale, Onslow County, North Carolina, in a fauna that is unique in western Atlantic localities. The fauna at Silverdale, which is thought to be early lower Miocene (Aquitanian) in age*, is more closely allied with the European localities of Miocene age and the Recent west American fauna than with any other western Atlantic fauna. Thus it was not totally unexpected that the only western Atlantic *Purpurellus* should appear here. From the modern disjunct distribution of the group it is obvious that there had to have been passage through the western Atlantic region, as the Recent species are found on the west coast of Africa and the west coast of tropical America but nowhere else. That it is also the earliest occurrence is perhaps fortuitious, but no specimens are reported before the Burdigalian in Europe.

It is difficult to compare this new species with its congeners for all are so very similar that they could quite comfortably be placed in synonymy but this would serve little purpose. Among the European species it is closest to *P. cyclopterus* (Millet, 1866), of which *P. gastaldii* (Bellardi, 1872) is probably a synonym, but differs in having a higher spire and more pronounced sutural indentation. *P. vernayi* (Paulucci) possesses marked spiral ribs, but has approximately the same shell shape as *P. repetiti*. *P. bellardii* (Seguenza), *P. latilabris* (Bellardi)

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* See Vokes, 1967, p. 140, for a discussion of the problems of a formational name for these beds at Silverdale.

and *P. ampistus* (de Gregorio) all differ in having a marked shoulder spine, which reminds one of the *Pterochelus* ancestry. The Recent species seem more akin to those latter forms than to the geographically intermediate *P. repetiti.*

This new species is based upon three, unfortunately all poor, specimens from the type locality. The holotype was collected by the writer and two unfigured paratypes are in the collection of Mr. Richard E. Petit, of Ocean Drive Beach, South Carolina, who kindly loaned them for comparison.

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## Genus POIRIERIA Jousseaume, 1880

### Subgenus POIRIERIA s.s.

*Poirieria* JOUSSEAUME, 1880, Le Naturaliste, Année 2, no. 42, p. 335.
Type species: *Murex zelandicus* Quoy and Gaimard, by original designation.

### POIRIERIA (POIRIERIA) WOODSENSIS E. H. Vokes, n. sp.

Plate 4, figs. 1a, 1b, 2a, 2b

*Murex morulus* Conrad. HARRIS, 1897, Acad. Nat. Sci. Phila., Proc., v. 48, p. 476, pl. 20, fig. 12 (*not* of Conrad).
*Phyllonotus morulus* (Conrad). HARRIS, 1899, Bulls. Amer. Paleontology, v. 3, no. 11, p. 63, pl. 8, fig. 7 (*not* of Conrad).
*Murex morulus* Conrad. WRIGLEY, 1930, Malac. Soc. London, Proc., v. 19, p. 105 (in part, *not* of Conrad).
*Eupleura morula* (Conrad). PALMER and BRANN, 1966, Bulls. Amer. Paleontology, v. 48, no. 218, p. 669 (in part, *not* of Conrad).

*Diagnosis*: Shell with three, possibly four, smooth conical nuclear whorls, ending at a small but pronounced varix; seven post-nuclear whorls in the adult. Axial ornamentation of seven varices on each post-nuclear whorl from the first to the last. On the whorls of the spire varices simple but bent back sharply into a large spine at the shoulder; on the body whorl three smaller spines between the shoulder and the siphonal canal with one additional spinelet on the canal. Spiral ornamentation almost totally lacking, only faint spiral threads visible in the intervarical areas. Aperture triangular in outline, opening into the shoulder spine and the smaller spines of the apertural varix. Inner lip with a callus, which is appressed at the posterior end but standing free at the anterior end. Both inner and outer lips completely smooth. Siphonal canal moderate in length, open, slightly recurved. In the adult a large false umbilicus is developed.

Dimensions of holotype: height 23 mm, diameter (including spines) 16 mm.
Holotype: ANSP 7059.
Type locality: Woods Bluff, Tombigbee River, Clarke County, Alabama.
*Occurrence*: Hatchetigbee Formation, Alabama; lower Eocene.
*Figured specimens*: Fig. 1, ANSP 7059 (holotype). Fig. 2, ANSP 7059a (paratype); height (incomplete) 37 mm, diameter 28 mm; locality same as holotype.

*Discussion*: The specimen figured by Harris (1897, pl. 20, fig. 12) as *Murex morulus*, from the lower Eocene beds of Alabama, is not that species but is a new species here named *P. woodsensis.* Wrigley (1930, p. 105) noted that this shell as figured by Harris was near *P. subcristatus* (d'Orbigny) from the London Clay, and added that the Midway and the Lignitic forms of "*Murex morulus*" were doubtfully the same. He stated that *P. subcristatus* "has a special importance in giving a clue to the affinities of the species, for in all essential characters it closely resembles the Recent *Murex zelandicus*, Quoy and Gaim., which is the genotype of *Poirieria*, Jousseaume, 1881." Wrigley's evaluation was absolutely correct. It is possible that the European *P. subcristatus* and the American *P. woodsensis* are conspecific and both are so close to *P. zelandicus* that they are scarcely to be distinguished.

In the type lot at the Academy of Natural Sciences of Philadelphia there are four specimens from Woods Bluff, Tombigbee River, Alabama. The largest of these, although incomplete, measures 37 mm in height, considerably larger than any known specimens of *P. harrisi* (new name for *Murex morulus* Conrad *non* Schröter) with which it was confounded by Harris. The aperture is completely lacking in any type of denticles, the chief characteristic separating the two subgenera *Poirieria* s.s. and *Paziella. P. harrisi* has five strong denticles on the outer lip.

The holotype of *P. woodsensis* is the smallest specimen in the type lot but is the best preserved and was selected for this reason. In all aspects it is the same as the larger specimens except for the development of a pronounced umbilicus in the largest specimen (see pl. 4, fig. 2). Harris noted that "in this collection there are specimens of various sizes, and they show one marked peculiarity. When small and young the an-

terior canal is long but curved; afterwards it seems to grow no more in length, but becomes extremely bent or twisted, and a large umbilicus is formed." (1897, p. 476).

Another species from the Hatchetigbee Formation of Alabama, also figured by Harris, is *Trophon caudatoides* Aldrich, 1886. Subsequently referred by some authors to the genus "*Murex*" it nevertheless seems more akin to *Trophon* than to *Murex*. The number of varices is more numerous on all whorls, both early and late. Unlike *Paziella*, which has about six varices on the adult body whorl, the type specimen of *T. caudatoides* has ten varices on the broken body whorl and 13 on the penultimate whorl.

### Poirieria (Poirieria) clenchi (Carcelles)

*Murex clenchi* Carcelles, 1953, Mus. Hist. Nat. Montevideo, Comun. Zool., v. 4, no. 70, p. 7, pl. 5, figs. 23-28.

*Diagnosis*: Shell muriciform, elongate, thin, fragile, porcelaneous white, almost transparent, with 5½ whorls and two nepeonic whorls; the spire is short, the last whorl is twice the rest of the shell, the aperture is semioval (in the complete example), very thin and almost completely separated from the last whorl, except above where it is united by a varical spine; in the broken example the aperture is subpyriform and is completely separated from the whorl. The labral edge is very angular at its posterior end; the columellar edge is thin, smooth and somewhat curved; the siphonal canal slightly deep and narrow, very elongate, being curved at the end, the deflection of the last segment is very accentuated; the sutural line slightly deep but well marked; the strip [anterior prolongation of the columellar lip] is separated from the edge of the canal, the whorls are very angular and from the continuation of the suture can be seen a slightly oblique zone, smooth and with fine growth striae; on the middle part of these whorls long, open (viewed from the front) ascending spines are borne; toward the bottom is noted a zone which has marked regular spiral striae which can be seen at a glance, these stop, truncated by the termination of the growth lines, in the angle of which are borne the spines which measure up to 16 mm in length, five spines may be counted on the last whorl, and seven on the penultimate and antepenultimate. (Carcelles, 1953, *translated*)

Dimensions of holotype: height 51.9 mm, diameter 25 mm.

Holotype: Mus. Nat. Hist. Montevideo no. 25146.

Type locality: Lat. 38° 24′ S, Long. 55° 36′ W, in 89.61 meters (off Bahia Blanca, Argentina).

*Occurrence*: Recent only, southern Atlantic.

*Discussion*: *P. clenchi* is a bizarre form, apparently most closely related to the other Southern Hemisphere species *P. zelandicus* from New Zealand. This species is unusual in that there is a marked tendency for the last whorl to become separated from the spire in a manner akin to that seen in the cancellarid genus *Trigonostoma*. This is the only muricine species at present known from the southern Atlantic; but this is probably a result of scant collecting rather than a true reflection of the fauna.

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## Subgenus Paziella Jousseaume, 1880

*Paziella* Jousseaume, 1880, Le Naturaliste, Année 2, no. 42, p. 335.
Type species: *Murex pazi* Crosse, by original designation.

*Bathymurex* Clench and Pérez Farfante, 1945, Johnsonia, v. 1, no. 17, p. 41.
Type species: *Murex* (*Bathymurex*) *atlantis* Clench and Pérez Farfante, by original designation.

*Dallimurex* Rehder, 1946, Nautilus, v. 59, p. 142.
Type species: *Murex nuttingi* Dall, by original designation.

### Poirieria (Paziella) harrisi E. H. Vokes, *nom. nov.*

Plate 4, figs. 3a, 3b

*Murex morulus* Conrad, 1860, Acad. Nat. Sci. Phila., Jour., (Ser. 2) v. 4, p. 293, pl. 47, fig. 28; Conrad, 1865, Amer. Jour. Conch., v. 1, no. 1, p. 16. *Non Murex morulus* Schröter, 1805.

*Murex morulus* Conrad. Aldrich, 1886, Alabama Geol. Surv., Bull. 1, pt. 1, p. 59.

*Murex morulus* Conrad. De Gregorio, 1890, Ann. Géol. Paléontologie, livr. 7, p. 95, pl. 7, fig. 35 (after Conrad, 1860).

*Murex morulus* Conrad. Cossmann, 1893, Ann. Géol. Paléontologie, livr. 12, p. 32.

*Trophon morulus* (Conrad). Harris, 1896, Bulls. Amer. Paleontology, v. 1, no. 4, p. 214, pl. 20, fig. 1.

Not *Murex morulus* Conrad. Harris, 1897, Acad. Nat. Sci. Phila., Proc., v. 48, p. 476, pl. 20, fig. 12 (= *P. woodsensis* Vokes, n. sp.).

Not *Phyllonotus morulus* (Conrad). Harris, 1899, Bulls. Amer. Paleontology, v. 3, no. 11, p. 63, pl. 8, fig. 7 (= *P. woodsensis*).

*Pagodula morula* (Conrad). Cossmann, 1903, Essais Paléoconch. Comp., v. 5, p. 193.

*Murex morulus* Conrad. Wrigley, 1930, Malac. Soc. London, Proc., v. 19, p. 105 (in part = *P. woodsensis*).

*Trophon morulus* (Conrad). Brann and Kent, 1960, Bulls. Amer. Paleontology, v. 40, no. 184, p. 884.

*Murex morulus* Conrad. Moore, 1962, Acad. Nat. Sci. Phila., Proc., v. 114, p. 78.

*Murex morulus* Conrad. E. H. Vokes, 1964, Malacologia, v. 2, no. 1, p. 15.

*Eupleura morula* (Conrad.) Palmer and Brann, 1966, Bulls. Amer. Paleontology, v. 48, no. 218, p. 669 (in part = *P. woodsensis*).

*Diagnosis*: "Fusiform, whirls angular, with distinct spines on the angle, two or three of which are produced; ribs longitudinal, oblique, foliated, acute; angle of body-whirl situated about the middle of the shell; beak sinuous, angle of aperture extending into an elongated, recurved spine." (Conrad, 1860)

Dimensions of holotype: height 15 mm, diameter (including spines) 11 mm.

Holotype: ANSP 14225.

Type locality: (?) Matthews Landing, Alabama River, Wilcox County, Alabama.

*Occurrence*: Matthews Landing Marl, Alabama; Paleocene.

*Figured specimen*: ANSP 14225 (holotype). Other occurrences: TU locality nos. 325, 735.

*Discussion*: This species, together with *Pterynotus matthewsensis*, is found in the Paleocene beds of Alabama, making it one of the oldest known muricine species.* It is not especially rare but it is a small form, the holotype being the largest specimen seen.

Harris (1897, pl. 20, fig. 12) figured a specimen from the lower Eocene Hatchetigbee Formation at Woods Bluff, on the Tombigbee River, Alabama, which he referred to "*Murex morulus*" but it is not the same species. Harris's specimen is here selected as the type of a new species given the name *P. woodsensis*. The name *Murex morulus* of Conrad is preoccupied by that of Schröter, 1805, and, therefore, a new name is here proposed.

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* A possibly identical form occurs in the Paleocene of Denmark, "*Murex*" *nanus* Ravn, 1939 (K. Danske Vidensk. Selsk., Biol. Skr., v. 1, no. 1, p. 78, pl. 3, fig. 7). Unfortunately that name is preoccupied by *Murex nanus* Anton, 1839, and thus is not available as a substitute name. Ravn's type material is a juvenile shell 2.8 mm in height so it is not certain that it is a synonym of *P. harrisi*, but it is suspiciously close, and hence will not be renamed here.

## Poirieria (Paziella) dominicensis (Gabb)

Plate 4, figs. 4a, 4b

*Trophon dominicensis* Gabb, 1873, Amer. Phil. Soc., Trans., (N. S.) v. 15, pt. 1, p. 202.

[*Murex*] *dominicensis* (Gabb). Dall, 1896, U. S. Natl. Mus., Proc., v. 19, no. 1110, p. 313.

*Murex* (*Trophon*) *werneri* Toula, 1911, K.-K. Geol. Reichsanst., Jahrb., v. 61, p. 479, pl. 29, figs. 9a, 9b.

*Trophon dominicensis* Gabb. Pilsbry, 1922, Acad. Nat. Sci. Phila., Proc., v. 73, p. 354, pl. 28, figs. 2, 3 (lectotype).

"*Trophon*" *dominicensis* Gabb. Woodring, 1928, Carnegie Inst. Washington, Publ. 385, p. 292.

"*Murex* (*Trophon*)" *werneri* Toula. Woodring, 1928, Carnegie Inst. Washington, Publ. 385, p. 292.

[*Paziella* (*Dallimurex*)] *dominicensis* (Gabb). Woodring, 1959, U. S. Geol. Surv. Prof. Paper 306-B, p. 217.

[*Paziella* (*Dallimurex*)] *werneri* (Toula). Woodring, 1959, U. S. Geol. Surv. Prof. Paper 306-B, p. 217.

[*Poirieria* (*Paziella*)] *dominicensis* (Gabb). E. H. Vokes, 1964, Malacologia, v. 2, no. 1, p. 18.

*Diagnosis*: "Shell small, broadly fusiform, thin; spire three-fifths the length of the mouth, turriculated; whorls eight, the first three nuclear, round and increasing very little in width, the other five widening more rapidly and angulated. Body whorl truncated above, with a rounded rib on the angle; above this the surface sinuous, convex nearest the suture and concave adjoining the angle; below the angle it is convex in the middle and rounds concavely into a moderate canal. Surface marked by from six to seven blunt varices, each bearing a single spire [*sic*] on the angle of the whorl. Between the varices the surface is shallowly excavated. Crossing both the varices and interspaces, below the angle, there are a few small revolving ribs. Aperture bi-angular posteriorly, narrowed gradually in advance; canal moderate in length, open; outer lip denticulated internally." (Gabb, 1873)

Dimensions of lectotype: height 17.5 mm, diameter (including spines) 11 mm.

Lectotype: ANSP 3252 (selected by Pilsbry, 1922, p. 354).

Type locality: Dominican Republic, exact locality unknown.

*Occurrence*: Gurabo Formation, Dominican Republic; middle Miocene. (?) Paraje Solo Formation, Veracruz, Mexico; (?) upper Miocene.

*Figured specimen*: ANSP 3252 (lectotype).

*Discussion*: The species named *Trophon dominicensis* by Gabb and that one named

*Murex* (*Trophon*) *werneri* by Toula seem certainly to be the same. The form is rare in both the Dominican Republic, from whence came "*Trophon*" *dominicensis*, and in the Isthmus of Tehuantepec, home of "*Murex*" *werneri*. Gabb had but two specimens in his type lot, one of which was selected by Pilsbry (1922, p. 354) as lectotype. The lectotype measures only 17.5 mm in height but the species attains a larger size for the holotype of "*Murex*" *werneri* is stated to be 30 mm and there is a specimen in the USNM collections that measures 20 mm. This latter specimen comes from the Gurabo Formation at Portrero, Dominican Republic.

The type locality of *Murex werneri* is near Almagres, Veracruz, a station on the Trans-Isthmian Railway, at Kilometer 70, a famous fossil locality in the early days on the railroad. (This is 70 kilometers measured from the terminus at Coatzacoalcos.) There is a great deal of minor faulting in this area and the writer has been unable to find any reference to the stratigraphic horizon exposed at K 70, but it may be the Paraje Solo Formation. This is the same formation in which another species of *Paziella* occurs, *P. septima* Vokes, n. sp. The presence of these two deep-water forms suggests that the Paraje Solo Formation may represent deeper water deposition than is commonly encountered in the fossil record.

Woodring (1959, p. 217) placed this species in the subgenus *Dallimurex* but the writer considers *Dallimurex* to be a synonym of *Paziella* s. s. and sees no reason for the distinction. *P. dominicensis* has about seven varices, which bear a single pointed spine at the shoulder. The spiral ornamentation consists of numerous, very faint spiral ribs and the outer lip is denticulated within.

Olsson (1964, p. 140, pl. 26, figs. 5, 5a) described a species, "*Boreotrophon*" *meridionalis*, from the Neogene (*i.e.*, late Miocene or Pliocene) Esmeraldas Formation of northwestern Ecuador.* This species is closely related to *P. dominicensis*, the principal difference between the Ecuadorian species and *P. dominicensis* being the development in the younger form of two smaller varical spines anterior to the primary spine at the shoulder. Both of these species have but six or seven varices; true *Boreotrophon* (type: *Murex clathratus* Linné) has many more, thinly laminar varices, and does not have the denticulated outer lip of these forms.

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* While this paper was in press Emerson and D'Attilio (1970, Veliger, v. 12, p. 271, pl. 39, figs. 3-6) described a Recent species from the Galápagos Islands, "*Murex*" *galapagana*, which is clearly the descendant of *P. meridionalis*. This is the first Recent record of the genus on the west coast of tropical America.

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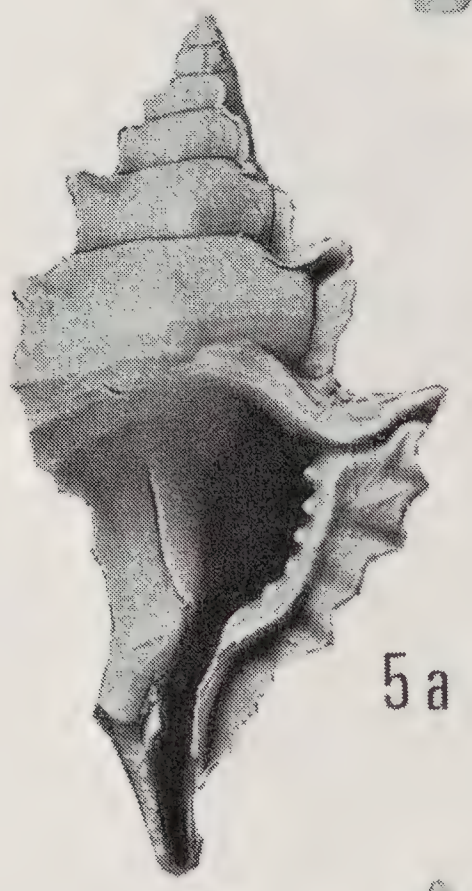
## Plate 1

Figures Page

1. *Pterynotus (Pterynotus) matthewsensis* (Aldrich) (×3) ..... 8
   PRI 24532; height 17.3 mm, diameter 7 mm.
   Locality: Matthews Landing, Alabama River, Alabama. Matthews Landing Marl, Paleocene.
2. *Pterynotus (Pterynotus) sabinola* (Palmer) (×4) ..... 9
   PRI 3012 (holotype); height 16 mm, diameter 9 mm.
   Locality: Sabine River, Texas. Stone City Beds, middle Eocene.
3. *Pterynotus (Pterynotus) weisbordi* (Palmer) (×1½) ..... 10
   PRI 4657 (holotype); height 33.5 mm, diameter 15 mm.
   Locality: Montgomery Landing, Red River, Louisiana. Moodys Branch Marl, upper Eocene.
4. *Pterynotus (Pterynotus) propeposti* (Mansfield) (×1½) ..... 11
   USNM 49545 (holotype); height 43 mm, diameter 20 mm.
   Locality: Blackwater Creek, Florida. (?) Suwannee Limestone, upper Oligocene.
5. *Pterynotus (Pterynotus) stenzeli* E. H. Vokes, n. sp. (×3) ..... 8
   TBEG 36637 (holotype); height 19 mm, diameter 11.3 mm.
   Locality: TBEG 173-T-19. Weches Fm., middle Eocene.



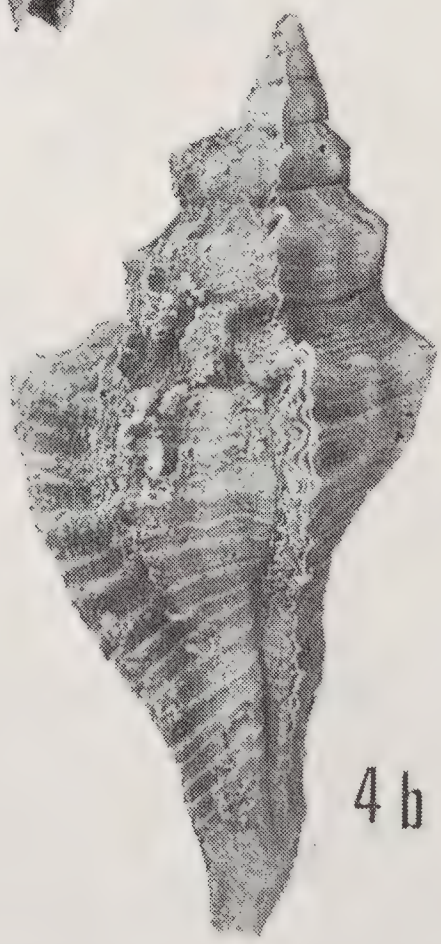


PLATE 1

### Poirieria (Paziella) septima
### E. H. Vokes, n. sp.

Plate 4, figs. 5a, 5b

*Diagnosis*: Seven whorls in the adult, nucleus unknown; spire greatly elevated. Axial ornamentation beginning on earliest whorls with seven simple varices, armed with a single sharp spine at the shoulder. Spiral ornamentation lacking on early whorls but gradually developing faint spiral ribs only on anterior portion of whorl; seven ribs on the body whorl, of which the central four are more prominent. Where spiral ribs cross the varices only slight crenulations formed. Nature of aperture not known but by analogy with related forms outer lip almost certainly bearing about a dozen small paired denticles. Siphonal canal open, moderately elongated, recurved, bearing no spinose processes.

Dimensions of holotype: height 33 mm, diameter 17 mm.

Holotype: USNM 646429.

Type locality: USGS 10631, Tuzendepetl [*i.e.*, Tuzantepetl], on Rio Coatzacoalcos, Lat. 18° 1′, Long. 94° 28′; about seven miles east-northeast of Minatitlán, Veracruz, Mexico.

*Occurrence*: Paraje Solo Formation, Veracruz, Mexico; (?) upper Miocene.

*Figured specimen*: USNM 646429 (holotype).

*Discussion*: Although based on four specimens from the Isthmus of Tehuantepec, none of the four is perfect and none has a complete aperture. Three of the specimens are from the collections of the Museum of Paleontology, University of California, Berkeley, and the fourth, the holotype, is from the U. S. National Museum. This new species is closely related to *P. dominicensis*, which occurs in the same area (as *P. werneri*), but may be distinguished by its larger size, higher spire, and less numerous spiral ribs. In general aspect *P. septima* is much like the Recent *P. nuttingi* and *P. oregonia*, lacking, however, the spines on the siphonal canal seen in the Recent forms. *P. dominicensis* is more akin to *P. pazi*, but also lacks the basal spines of the Recent form. This parallel development is interesting in that none of the fossil species of *Paziella* possess these basal spines but most of the Recent species do have them. Only *P. atlantis*, in the Recent fauna, does not have these spines and for this reason was made the type of a new subgenus, *Bathymurex,* by Clench and Pérez Farfante (1945, p. 41). In view of the otherwise almost identical nature of the fossil and Recent species this separation does not seem justified and *Bathymurex* is considered a synonym of *Paziella.*

### Poirieria (Paziella) pazi (Crosse)

Plate 5, fig. 1

*Murex pazi* Crosse, 1869, Jour. de Conchyl., v. 17, p. 183; Crosse, 1870, *ibid.*, v. 18, p. 99, pl. 1, fig. 4.

*Murex pazi* Crosse. G. B. Sowerby, Jr., 1879, Thes. Conch., v. 4, *Murex*, pl. 22, fig. 208.

*Murex* (*Phyllonotus*) *pazi* Crosse. Dall, 1889, Harvard Mus. Comp. Zool., Bull., v. 18, p. 199, pl. 15, fig. 1; Dall, 1889, U. S. Natl. Mus., Bull. 37, p. 120, pl. 15, fig. 1.

*Murex* (*Poirieria*) *pazi* Crosse. Clench and Pérez Farfante, 1945, Johnsonia, v. 1, no. 17, p. 44, pl. 23, figs. 1-3.

[*Poirieria* (*Paziella*)] *pazi* (Crosse). E. H. Vokes, 1964, Malacologia, v. 2, no. 1, p. 17, pl. 2, figs. 36, 65.

*Diagnosis*: "T. breviter fusiformis, sat tenuis, paululum, translucida, unicolor, alba; spira elongata, apice subacute mamillato, laeviusculo; sutura sat profunde impressa, subirregularis varicibus interrupta; anfr. 8-8½ septemvaricosi; primi subangulati, vix aut non spinosi, penultimus varicibus in spinas longiusculas, excavatas desinentibus instructus, ultimus spiram paulo superans, transversim obsoletissime sulcato-striatus, spinis triseriatim dispositis et varicibus correspondentibus ornatus, primis valde elongatis, rectis, ad angulum anfractus, secundis minutis, parum prominulis, versus medium, tertiis longiusculis, subacutis, circa canalem sitis; apertura rotundato-subovata, intus sulcata, alba, in canalem longiusculum, subrecurvum, desinens; perist. album, margine columellari laevigato, subarcuato." (Crosse, 1869)

Dimensions of holotype: height 35 mm, diameter (including spines) 29.5 mm.

Holotype: Collection of Journal of Conchyliologie (Clench and Pérez Farfante, 1945, p. 45).

Type locality: "Maris Antillarum."

*Occurrence*: Recent only.

*Figured specimen*: USNM 678944; height 39 mm, diameter (excluding spines) 19 mm; locality, *Silver Bay* Station 2481, off Hollywood, Florida, in 200 fathoms.

*Discussion*: From the collections made by the U. S. Fish and Wildlife Service M/V *Oregon* and *Silver Bay* it can be seen that there are two forms of *P. pazi.* One of these is the relatively smooth type, as figured by the original author and by Clench and Pérez Farfante (1945, pl. 44, figs. 1-3). The other is a more heavily ornamented shell such as the one figured by Sowerby (1879, fig. 208). The smooth form is apparently confined to the outer side of the Antilles from approxi-

mately north of Havana, Cuba, eastward and along the east Florida coast. The second form is found along the edge of the continental shelf from the Florida Straits around to Honduras. The two forms occur together in the Florida Straits. H. R. Bullis, Jr., Director of the U. S. Bureau of Commercial Fisheries Research Base at Pascagoula, Mississippi, who first noted this division (1964, p. 106), refers to these two forms as "Continental" and "Antillian" (personal communication).

*P. pazi* is variable in the formation of the apertural lips, both inner and outer. Many specimens do not have these lips and thus resemble *Poirieria* greatly. The specimen here figured shows a completely formed inner and outer lip, marked by denticulations on the outer lip. With these lips developed the resemblance to *P. nuttingi*, type of *Dallimurex*, and *P. atlantis*, type of *Bathymurex*, is more evident. The holotype of *P. nuttingi* (here figured, pl. 5, fig. 4) does not have a complete aperture but other specimens show that when completed the aperture of this species is identical to *P. pazi* and *P. oregonia* (Bullis).

*P. pazi* is an inhabitant of deep water with records ranging from 112 to 338 fathoms, most being deeper than 200 fathoms (Springer and Bullis, 1956, p. 29; Bullis and Thompson, 1965, p. 15; Clench and Pérez Farfante, 1945, p. 45). It is not rare at these depths being reported from 14 stations by these authors, and it also has been taken at a dozen or more additional stations by the *Oregon* and *Silver Bay*.

## Poirieria (Paziella) atlantis (Clench and Pérez Farfante)

Plate 5, figs. 2a, 2b

*Murex* (*Bathymurex*) *atlantis* Clench and Pérez Farfante, 1945, Johnsonia, v. 1, no. 17, p. 41, pl. 21, figs. 3-5.

[*Poirieria* (*Paziella*)] *atlantis* (Clench and Pérez Farfante). E. H. Vokes, 1964, Malacologia, v. 2, no. 1, p. 17, pl. 2, fig. 31.

*Diagnosis*: "Shell small, about 23 mm (about one inch) in length, rather thin and spinose. Whorls seven and strongly convex. Color a dull white. Spire well extended. Suture deeply impressed. Aperture subcircular, small and porcellaneous white within. Parietal lip smooth, adnate above and very slightly free below. Palatal lip smooth but possessing a series of small denticles below the margin on the lower half of the lip. Siphonal canal narrow, long, recurved upward and angled toward the right near the base. Previous siphonal canals remain as spur-like spines, the last one almost as long as the present canal, making it appear bifurcated. Axial sculpture consists of six low varices, each of which supports a rather long, slightly recurved, single, open spine at the shoulder of the whorl. Below this spine there are a few small knobs where the spiral ribs cross. Spiral sculpture consists of numerous fine and coarse ribs, the coarse ribs forming the little knobs as they pass over the varices. Nuclear whorls one and one-half, small, smooth and rounded, the first whorl moderately twisted. Post nuclear whorls similar to the latter whorls but having the shoulder spine relatively smaller. Operculum unknown. No periostracum." (Clench and Pérez Farfante, 1945)

Dimensions of holotype: height 23.5 mm, diameter (excluding spines) 10.5 mm.

Holotype: Harvard MCZ 164684.

Type locality: *Atlantis* Station 3333, Bahía de Cochinos, Santa Clara Province, Cuba, in 190 to 200 fathoms.

*Occurrence*: Recent only.

*Figured specimen*: Harvard MCZ 164684 (holotype).

*Discussion*: *P. atlantis* is based on a single specimen from the south side of Cuba. The holotype differs from *P. pazi* only in lacking the row of spines encircling the base of the canal. For this reason the species is not placed in synonymy but it is suspected that more material might change this decision.

As was noted above in the discussion of *P. septima* n. sp., *P. atlantis* is the only Recent species lacking the basal row of spines. If *P. atlantis* is a valid species then it represents the more primitive form of *Paziella*. It may be that this single specimen is an aberrant shell for, in spite of large collections made in the western Atlantic region by the U. S. Fish and Wildlife vessels, no more specimens have been taken. However, H. R. Bullis, Jr., Base Director of the U. S. Fisheries Station at Pascagoula, Mississippi, who is in charge of these vessels, has observed (*in litt.*): "Cuba has provided a tremendous number of type localities while remaining one of the most poorly known faunas of the entire western Atlantic as far as I am concerned. It does not seem at all unreasonable that the *atlantis* could as easily turn out to be one of the most common species of the island once it has been properly surveyed."

### Poirieria (Paziella) nuttingi (Dall)

Plate 5, figs. 4a, 4b

*Murex nuttingi* Dall, 1896, University Iowa, Lab. Nat. Hist., Bull., v. 4, no. 1, pt. 2, p. 13, pl. 1, fig. 1.

*Murex (Murexsul) nuttingi* Dall. Clench and Pérez Farfante, 1945, Johnsonia, v. 1, no. 17, p. 49, pl. 25, fig. 5.

*Paziella (Dallimurex) nuttingi* (Dall). Rehder, 1946, Nautilus, v. 59, p. 142.

[*Poirieria (Paziella)*] *nuttingi* (Dall). E. H. Vokes, 1964, Malacologia, v. 2, no. 1, p. 17, pl. 2, fig. 30.

*Diagnosis*: "Shell white with a pale straw-colored epidermis and eight whorls exclusive of the (lost) nucleus; suture deep, whorls rounded (the last) crossed by eight varices, each bearing a rather long grooved spine at the shoulder and anteriorly about six smaller and less conspicuous spinules, each of which corresponds to a more or less distinct revolving thread; at the shoulder and behind it there is no revolving sculpture or only faint traces of it; the apical three or four whorls show angular points, rather than spines, which are partly the result of wear; canal rather long, shorter than the spire, with a wreath midway of long recurved spines, each corresponding to a varix; the siphonal fasciole imbricated by the canal-ends of successive resting-stages; pillar white, moderately callous; canal open; outer lip modified by the sculpture, not lirate; operculum pale-brown, kite-shaped, the nucleus at the acute end which is nearly straight." (Dall, 1896)

Dimensions of holotype: height 44.4 mm, diameter (excluding spines) 20.5 mm.

Holotype: USNM 107372.

Type locality: Eight miles east of Sand Key (near Key West), Florida, in 15 fathoms.

*Occurrence*: Recent only.

*Figured specimen*: USNM 107372 (holotype).

*Discussion*: "*Murex*" *nuttingi* Dall was selected by Rehder (1946, p. 142) to be the type species of a new subgenus, *Dallimurex*, said to differ from *Paziella* "in having stronger laminated varices, which have the spine on the shoulder shorter and stouter, and which bear numerous shorter spines below the shoulder. The whorls below the shoulder have strong irregular spiral ridges, which culminate in the varical spines." The two Recent species he included in this new subgenus are *P. nuttingi* and "*Murex*" *carnicolor*, here referred to *Poirieria* (*Panamurex*). The description of the subgenus was a combination of the features of these two species for the strong spiral ridges seen in *P. carnicolor* are greatly reduced in *P. nuttingi* and although *P. nuttingi* is more spinose than *P. pazi* the differences are of a specific rather than generic degree. Bullis (1964, p. 106) noted that "*Murex pazi* and *M. nuttingi* are more similar in shell characters than has been previously indicated, with the former showing a great range of sculpturing." The fossil species, for which in part the new subgenus was proposed, are *P. lychnia* and *P. fusinoides* from the Chipola Formation, both here placed in the subgenus *Panamurex*, which has strong spiral sculpture.

The type specimen of *P. nuttingi* is said to have come from a depth of 15 fathoms but the species usually lives much deeper. It has been reported only from 110 fathoms (Springer and Bullis, 1956, p. 28) and 200 fathoms (Bullis and Thompson, 1965, p. 15). It also was taken at *Oregon* Station 1255 in 120 fathoms.

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### Plate 2

Figures — Page

1. *Pterynotus (Pterynotus) burnsii* (Aldrich) (× 1¼) ..... 10
   USNM 135155 (holotype); height 67.5 mm, diameter 33 mm.
   Locality: Carson's Creek, Mississippi. Red Bluff Clay, lower Oligocene.
2. *Pterynotus (Pterynotus) postii* (Dall) (× 1½) ..... 12
   USNM 130349 (holotype); height 38 mm, diameter 21 mm.
   Locality: Ballast Point, Tampa Bay, Florida. Tampa Limestone, lower Miocene.
3. *Pterynotus (Pterynotus) hoerlei* E. H. Vokes, n. sp. (× 1½) ..... 12
   USNM 645616 (holotype); height 59 mm, diameter 29.5 mm.
   Locality: TU 547. Chipola Fm., (?) lower Miocene.

PLATE 2

### Poirieria (Paziella) oregonia (Bullis)

Plate 5, fig. 3

*Murex* (*Poirieria*) *oregonia* Bullis, 1964, Tulane Stud. Zool., v. 11, no. 4, p. 106, figs. 5, 6.

*Diagnosis*: "Shell heavy, elongate, and strongly sculptured. Apex eroded (as are all mature specimens in the series), 8 whorls remaining. Aperture elongate, leading into an extended siphonal canal. Outer lip flared, sharp, somewhat crenulate on the edge and with 13 teeth on the inner margin; the lip supports a strong, upturned, imbricate and hollowed spine at the shoulder. Parietal wall with a raised, erect, shield-like callus. Spire turreted, with a deep, irregular suture. Spiral sculpturing of eight strong cords between the base and shoulder. Axial sculpture of nine varices supporting eight upturned imbricate spines which correspond to the cords, plus the shoulder spine, and a pair of long spines on the base of the siphonal canal. The penultimate whorl has eight varices with the sub-shoulder spines absent, but with nodules at the crossing of the cords and varices, with three cords left exposed. On the rest of the spire only two cords are exposed. The varices cross the shoulder with a step-like overlapping of the succeeding section. Growth lines in the form of undulating wrinkles are most evident on the shoulder. The eight spines below the shoulder on the last varix are imbricately doubled and not directly connected to the margin of the lip. The second varix is similar but a few of the forward spines directly receive involutions of the former lip. This is more so on the third varix and entirely the case on the fourth. Five previous anterior canals are present. Operculum dark reddish-brown, unguiculate, broadly oval with a terminal apex, and strongly sculptured with growth lines. The radula is large; the rachidian has five cusps of about equal length. The middle and outer two cusps are slightly stouter. The laterals are triangulate and hooked." (Bullis, 1964)

Dimensions of holotype: height 85.2 mm, diameter (excluding spines) 37.8 mm.

Holotype: USNM 635149.

Type locality: *Oregon* Station 2023, 95 miles north of Pte. Mana, French Guiana, in 135 fathoms.

*Occurrence*: Recent only, from Trinidad south to the Equator along the coast of Brazil.

*Figured specimen*: USNM 635149 (holotype).

*Discussion*: *P. oregonia* is closely related to *P. nuttingi* (Dall) but is much larger than that species. It also may be distinguished from *P. nuttingi* by the presence of two rows of spines on the siphonal canal in place of the single row seen in *P. nuttingi*. It is a deep-water form, records ranging from 105 to 275 fathoms; however, it is not rare at these depths for Bullis reported over 175 paratypes, including 150 at one locality.

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## Subgenus Flexopteron Shuto, 1969

*Flexopteron* Shuto, 1969, Mem. Fac. Sci., Kyushu Univ., Ser. D, Geol., v. 19, no. 1, p. 111.

Type species: *Flexopteron philippinensis* Shuto, by original designation.

### Poirieria (Flexopteron) collata (Guppy)

Plate 4, figs. 6a, 6b

*Murex collatus* Guppy, 1873, Sci. Assoc. Trinidad, Proc., v. 2, p. 83, pl. 1, fig. 8; Guppy, 1874, Geol. Mag., (Decade 2) v. 1, p. 433, 438; pl. 16, fig. 8.

*Muricidea collata* (Guppy). Dall, 1903, Wagner Free Inst. Sci., Trans., v. 3, pt. 6, p. 1584.

*"Muricopsis" collatus* (Guppy). Woodring, 1928, Carnegie Inst. Washington, Publ. 385, p. 291, pl. 17, figs. 10, 11 (holotype).

[*Paziella* (*Dallimurex*)] *collatus* (Guppy). Woodring, 1959, U. S. Geol. Surv. Prof. Paper 306-B, p. 217.

[*Poirieria* (*Paziella*)] *collatus* (Guppy). E. H. Vokes, 1964, Malacologia, v. 2, no. 1, p. 18.

*Diagnosis*: "Ovate, rimate, slightly flattened, adorned with numerous thin slightly fimbriate or crenulate varices often doubled, especially the later ones; about seven on the last whorl; their interstices indistinctly crossed by low transverse costae which terminate in points on the varices; the upper point large, acute and projecting, giving an angulate appearance to the shell; varices uniting below to form an irregular and contorted canal. Whorls 6-7, somewhat angulate. Spire sharp. Outer lip expanded and crenulate, obtusely dentate within. Pillar-lip smooth." (Guppy, 1873)

Dimensions of holotype: height 22 mm, diameter 15 mm.

Holotype: USNM 115479.

Type locality: Bowden, Jamaica (= TU 705).

*Occurrence*: Bowden Formation, Jamaica; (?) upper Miocene.

*Figured specimen*: USNM 115479a (paratype); height 20 mm, diameter 13 mm, locality same as holotype. Other occurrences: TU locality no. 705.

*Discussion*: There are two specimens in the type lot of Guppy's "*Murex*" *collatus*. Woodring (1928, p. 291) identified and figured the larger of the two as the holotype but the slightly smaller second specimen is better preserved and shows the fine details of ornamentation missing in the holotype. Therefore, the paratype is here figured. This specimen does not show the strong denticu-

lations seen on the outer lip of the holotype. The species is not especially rare at the type locality, the writer has collected three incomplete examples there, but it is known from nowhere else.

The generic placement of this species has proved difficult to authors, as may be seen in the above synonymy. The writer (Vokes, 1964, p. 18) referred the form to the subgenus *Paziella* with, however, some unexpressed doubt. In a work on the Neogene gastropods of the Philippine Islands, Shuto (1969, p. 111) has proposed a new genus *Flexopteron* with the type a new species, *F. philippinensis*. This new species (*loc. cit.*, p. 112, pl. 8, figs. 1, 2) is very much like "*M.*" *collatus* and it seems reasonable to include the Caribbean species in this new group. Shuto placed *Flexopteron* in the family Coralliophilidae but the relationship seems to lie with the *Poirieria-Paziella* line.

*P. collata* occurs in the Bowden Formation of Jamaica. The age assigned to this formation by Woodring (1928, p. 39) was upper middle Miocene (Tortonian). This age assignment has been questioned by the writer (Vokes, 1967, p. 154) and it seems probable that the beds are younger, perhaps even Pliocene, in age. The ecology of the Bowden Formation is very unusual. Woodring (*ibid.*, p. 28-38) gave an excellent discussion of the ecologic implications of the genera present and concluded that the formation represents "deposition along an unusually steep slope in which a narrow coastal shelf was cut and (that) at times the sediments at the edge of the shelf and the shells buried in them were washed down the slope and came to rest at a greater depth, where they were mixed with autochthonous material" (*ibid.*, p. 35-36). This is a reasonable explanation for the mixture of shallow and deep water genera found in a matrix of coarse volcanic rock debris, including boulders as much as six inches in diameter. Unfortunately there are no living representatives of the *Flexopteron* line known to the writer so no ecologic information can here be deduced that might help prove or disapprove this deep-water hypothesis.

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## Subgenus PAZINOTUS E. H. Vokes, n. subgen.

Type species: *Eupleura stimpsonii* Dall, 1889, Recent, off Barbados, B.W.I., 100 fathoms.

*Etymology*: An arbitrary combination of *Paziella* and *Pterynotus*. *Gender*: Masculine.

*Description*: Shell small. Axial ornamentation consisting of a variable number of varices, from four to seven; varices formed by lamellar flanges connecting varical spines, which are a reflection of the spiral ribs ornamenting the shell. Spiral ornamentation moderate in development. Aperture bearing strong denticulations on outer lip; smaller denticulations at anterior end of columellar lip. Siphonal canal open, short, slightly recurved.

### POIRIERIA (PAZINOTUS) BOWDENENSIS E. H. Vokes, n. sp.

Plate 5, figs. 5a, 5b

"*Muricopsis*" species WOODRING, 1928, Carnegie Inst. Washington, Publ. 385, p. 292, pl. 18, fig. 1.

*Dallimurex* species WOODRING, 1959, U. S. Geol. Surv. Prof. Paper 306-B, p. 217.

*Diagnosis*: "Shell small, slender. Anterior canal relatively long, narrow, tip recurved, projecting shelf broken on only specimen. Umbilical opening absent. Interior of outer lip bearing six heavy denticles. Sculpture consisting of lamellar varices (7 on body whorl). Those on spire bearing spines on shoulders; those on body whorl bearing spines on and below shoulder, but the shoulder spines are longest. Between the varices widely spaced low spiral cords." (Woodring, 1928)

Dimensions of holotype: height 13.9 mm, diameter 6 mm.

Holotype: USNM 369621.

Type locality: Bowden, Jamaica (= TU 705).

*Occurrence*: Bowden Formation, Jamaica; (?) upper Miocene.

*Figured specimen*: USNM 369621 (holotype).

*Discussion*: This unique specimen from the Bowden Formation of Jamaica is the only known fossil example of the subgenus *Pazinotus* in the New World. As the Recent species of the group occur in water from 40 to 100 fathoms in depth, the presence of a specimen of *Pazinotus* at Bowden helps to corroborate Woodring's (1928, p. 35-36) deep-water hypothesis for the origin of the formation. (See under *P. collata*, above, for further discussion.)

Woodring (*ibid.*, p. 292) suggested that this specimen is a juvenile but it has six

post-nuclear whorls and must be almost an adult. The type of the Recent *P. stimpsonii* is slightly smaller and has only five whorls.

## Poirieria (Pazinotus) stimpsonii (Dall)

Plate 5, figs. 6a, 6b, 7a, 7b

*Eupleura stimpsonii* Dall, 1889, Harvard Mus. Comp. Zool., Bull., v. 18, p. 204.
*Eupleura stimpsoni* Dall. Dall, 1889, U. S. Natl. Mus., Bull. 37, p. 120, pl. 42, fig. 3; Dall, 1890, U. S. Natl. Mus., Proc., v. 12, no. 773, p. 331, pl. 11, fig. 3.
*Eupleura stimpsoni* Dall. M. Smith, 1953, Illus. Cat. Recent Species Rock Shells, p. 17, pl. 13, fig. 24.
*Eupleura stimpsoni* Dall. Abbott, 1954, American Seashells, fig. 47a (not in text); Abbott, 1968, North American Seashells, p. 126, fig. 9.

*Diagnosis*: "Shell small, thin, whitish, not polished, with four varices to the whorl and five whorls; nucleus smooth, white; spiral sculpture of extremely fine faint striae, and of (on the last whorl) five low keels, most prominent on the back of the varices. The posterior keel is produced at the shoulder as a spine, which on the front side of the varix looks as if it were holding up the webbing of the varix as a tent-pole holds a tent; the other keels are represented on the front of the varix only by shallow grooves. The transverse sculpture is composed of well marked incremental lines; above the spine on the last whorl the web of the varix extends to the fifth preceding varix; below the spine it follows the outline of the aperture, nearly, and terminates midway down the canal; the margin is even except at the spine and the ends of the grooves; aperture rounded, continuously marginate except at the open narrow canal; there are four teeth inside the outer lip in front of the spine, and three near the front of the inner lip; the canal is slightly recurved, the end of the antecedent canal projecting from it at the left; suture well marked." (Dall, 1889)

Dimensions of lectotype: height 12 mm, diameter 7 mm.

Lectotype (here designated): USNM 87087.

Type locality: *Blake* Station (unnumbered), off Barbados, 100 fathoms.

*Occurrence*: Recent only.

*Figured specimens*: Fig. 6, USNM 87087 (lectotype). Fig. 7, MCZ 7310 (lectoparatype); height 11 mm, diameter 7.4 mm; locality same as lectotype.

*Discussion*: Although this species was referred to the genus *Eupleura* by Dall there are several obvious differences in the two forms. The primary characteristic of the genus *Eupleura* is the development of a single pair of varices on opposite sides of the shell, giving the aspect of an *Apollon*. True *Eupleura* also lacks the flaring trumpet-like parietal lip seen in *P. stimpsonii*, which is identical to that seen in *P. paziella* (compare pl. 5, figs. 1 and 6), as well as the deflected siphonal canal of the latter two species.

In the type lot of this species there are nine specimens; four are at the Harvard University Museum of Comparative Zoology and five at the U. S. National Museum. All were labeled as "types" by Dall, but one specimen, here designated as lectotype, matches his

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## Plate 3

Figures — Page

1. *Pterynotus (Pterynotus) havanensis* E. H. Vokes, *nom. nov.* (× 4) ..... 13
MCZ 7308 (holotype-*Murex tristichus* Dall); height 15.5 mm, diameter 10 mm.
Locality: *Blake* Station 51, off Havana, Cuba, 400 fms. Recent.
2. *Pterynotus (Pterynotus) bushae* E. H. Vokes, *nom. nov.* (× 4) ..... 13
MCZ 6918 (holotype-*Murex pygmaeus* Bush); height 16 mm, diameter 8.5 mm.
Locality: *Blake* Station 319, off Charleston, South Carolina, 262 fms. Recent.
3. *Pterynotus (Pterynotus) phaneus* (Dall) (× 4) ..... 14
USNM 93256 (holotype); height 17 mm, diameter 7 mm.
Locality: *Albatross* Station 2662, off St. Augustine, Florida, 434 fms. Recent.
4. *Pterynotus (Purpurellus) repetiti* E. H. Vokes, n. sp. (× 1¼) ..... 16
USNM 646438 (holotype); height 53.5 mm, diameter 28 mm.
Locality: TU 866. "Silverdale Beds," lower Miocene.
5. *Pterynotus (Pterochelus) angelus* (Aldrich) (× 2) ..... 15
USNM 644608 (holotype); height 26 mm, diameter 14 mm.
Locality: Red Bluff, Chickasawhay River, Mississippi. Red Bluff Clay, lower Oligocene.

PLATE 3

cited dimensions and was undoubtedly the figured specimen. No others are as large.

Dall described the species as having "four varices to the whorl," but in the type specimen and one other of the type lot there are four and one-half varices to a whorl and in four of the remaining seven lectoparatypes there are five varices on the body whorl. Only two specimens have four varices on the body whorl but each of these has four and one-half on the earlier whorls. One specimen is fragmentary and it cannot be ascertained how many varices it had. In general it can be said that the species has four and one-half to five varices on the body whorl.

Abbott (1968, p. 126) stated that the body whorl of this species has seven or eight varices, but examination of his specimens reveals only five on one, and six on a second. His specimens were taken in 66-70 fathoms, 90 miles southwest of Egmont Key, Florida (at the mouth of Tampa Bay). Numerous specimens have been taken in this same general area by Jim Moore of Palmetto, Florida, who dredges near Anna Maria Key. One of the specimens in the type lot came from 1000 fathoms off Cape San Antonio, at the western tip of Cuba, however this was a dead shell and probably did not live at this extreme depth. Smith's (1953, p. 17) reference to an occurrence off Fernandina, Florida, in 294 fathoms is an error for *Urosalpinx stimpsoni* Dall, a different species.

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Subgenus PANAMUREX Woodring, 1959

*Panamurex* WOODRING, 1959, U. S. Geol. Surv. Prof. Paper 306-B, p. 217.
Type species: *Murex gatunensis* Brown and Pilsbry, by original designation.

### POIRIERIA (PANAMUREX) MACNEILI
E. H. Vokes, *nom. nov.*

Plate 6, figs. 1a, 1b, 2a, 2b

*Murex simplex* ALDRICH, 1886, Alabama Geol. Surv., Bull. 1, pt. 1, p. 19, pl. 5, fig. 8. *Non Murex* (*Typhis*) *simplex* Philippi, 1841.
*Murex simplex* Aldrich. MEYER, 1886, Alabama Geol. Surv., Bull. 1, pt. 2, p. 74.
[*Ocinebra* (*Favartia*)] *simplex* (Aldrich). DALL, 1890, Wagner Free Inst. Sci., Trans., v. 3, pt. 1, p. 150.
[*Poirieria* (*Panamurex*)] *simplex* (Aldrich). E. H. VOKES, 1964, Malacologia, v. 2, no. 1, p. 18.

*Diagnosis*: "Shell short, stout; whorls probably five; suture deeply impressed; varices numerous, very large and broadly rounded, terminating above near the suture in sharp points; seven on the body whorl, numerous coarse raised revolving lines cover the whorls; aperture small, elliptical, terminating anteriorly in a nearly closed canal; outer lip thickened and crenate within; three folds appear upon the columella." (Aldrich, 1886)

Dimensions of holotype: height 15.5 mm, diameter 9 mm.

Holotype: USNM 644618.

Type locality: "Bryan's Ferry" (*i.e.*, Byram), Hinds County, Mississippi (= TU 66).

*Occurrence*: Byram Marl, Mississippi; middle Oligocene.

*Figured specimens*: Fig. 1, USNM 644618 (holotype). Fig. 2, USNM 646432 (topotype); height 23.5 mm, diameter 12.3 mm; locality, Byram, Hinds County, Mississippi.

*Discussion*: The holotype of *P. macneili* is a juvenile specimen but from other larger specimens in the collections of the U. S. National Museum it can be seen that this species is much like the younger *P. heilprini* and *P. fusinoides*. It is the oldest known form referable to *Panamurex* and bears the characteristic denticulations upon the inner lip.

The name *Murex simplex* of Aldrich is preoccupied by that of Philippi, therefore the writer takes pleasure in renaming this species after F. S. MacNeil, a longtime student of the Oligocene faunas.

### POIRIERIA (PANAMUREX) HEILPRINI
(Cossmann)

Plate 6, figs. 3a, 3b, 4

*Murex spinulosa* HEILPRIN, 1887, Wagner Free Inst. Sci., Trans., v. 1, p. 108, pl. 15, fig. 41. *Non Murex spinulosus* Deshayes, 1835.
*Murex* (*Chicoreus*?) *burnsii* Whitfield. DALL, 1890, Wagner Free Inst. Sci., Trans., v. 3, pt. 1, p. 141 (in part, *not* of Whitfield).
*Muricidea spinulosa* (Heilprin). DALL, 1890, Wagner Free Inst. Sci., Trans., v. 3, pt. 1, p. 149, pl. 8, fig. 9 (in part = *P. lychnia*).
*Muricopsis heilprini* COSSMANN, 1903, Essais Paléoconch. Comp., v. 5, p. 34. New name for *Murex spinulosa* Heilprin *non* Deshayes.
*Muricidea spinulosa* (Heilprin). DALL, 1903, Wagner Free Inst. Sci., Trans., v. 3, pt. 6, p. 1566.
*Chicoreus burnsii* (Whitfield). DALL, 1915, U. S. Natl. Mus., Bull. 90, p. 75 (in part, *not* of Whitfield).
*Muricidea heilprini* (Cossmann). DALL, 1915, U. S. Natl. Mus., Bull. 90, p. 76, pl. 7, fig. 4.
"*Muricidea*" *heilprini* (Cossmann). MANSFIELD, 1937, Florida Geol. Surv., Bull. 15, p. 132.

"*Murex spinulosa*" Heilprin. Woodring, 1959, U. S. Geol. Surv. Prof. Paper 306-B, p. 218.

*Diagnosis*: "Shell elevated, elongated, about equally attenuated to both extremities; whorls strongly angulated superiorly, bearing short, outwardly directed, spines on the shoulder angulation; a row of similar (supra-basal) spines in the siphonal region; aperture about one-half the length of shell, the canalicular portion the longest; umbilicus long and open; surface of shell below the shoulder with a limited number of prominent revolving lines, four on the body-whorl. (Heilprin, 1887)

Dimensions of holotype: "Length, slightly exceeding one inch; width, half-inch." (Heilprin, 1887, p. 108).

Holotype: Wagner Free Inst. Sci. 870.

Type locality: Ballast Point, Tampa Bay, Hillsborough County, Florida.

*Occurrence*: Tampa Limestone, Florida; lower Miocene.

*Figured specimens*: Fig. 3, USNM 165089; height 23.5 mm, diameter 13 mm. Fig. 4, USNM 112065; height 10 mm, diameter 7 mm. Locality of both, Ballast Point, Tampa Bay, Florida.

*Discussion*: According to Mansfield (1937, p. 132) this species is "quite common" at the type locality. There are numerous specimens in the collections of the U. S. National Museum but none are well preserved. The small specimen figured here (plate 6, fig. 4) is perhaps the best of the lot. This is the specimen that Dall (1890, p. 141; 1915, p. 75) considered to be a juvenile of "*Murex*" *burnsii* Whitfield. Whitfield's holotype has been recently figured by the writer (Vokes, 1968a, pl. 7, fig. 2) and it can be seen that the two species resemble each other only slightly.

*P. heilprini* is closely related to the middle Oligocene *P. macneili*, the principal difference in the two species being the stronger, more numerous spiral ribs of the older form. *P. heilprini* has five weak spiral ribs, including that at the shoulder, but *P. macneili* has seven moderately strong ribs. *P. heilprini* is also much like the younger Chipola species *P. fusinoides*. The spiral ornamentation in *P. fusinoides* is stronger than that of *P. heilprini* but because of the poor preservation of the Tampa specimens the differences may not be as great as they appear.

Woodring (1959, p. 218) did not include *P. heilprini* in his subgenus *Panamurex* but stated that it "evidently represents a different muricine genus." In view of the strong similarity between the three species noted above, two of which are definitely to be referred to *Panamurex*, it seems unreasonable not to include *P. heilprini* also.

## Poirieria (Panamurex) laccopoia (Gardner)

Plate 7, figs. 1a, 1b

*Muricopsis laccopoia* Gardner, 1947, U. S. Geol. Surv. Prof. Paper 142-H, p. 529, pl. 52, figs. 40, 41.

[*Paziella* (*Panamurex*)] *laccopoia* (Gardner). Woodring, 1959, U. S. Geol. Surv. Prof. Paper 306-B, p. 217 (in synonymy of *P. fusinoides*).

[*Poirieria* (*Panamurex*)] *laccopoia* (Gardner). E. H. Vokes, 1964, Malacologia, v. 2, no. 1, p. 18.

"*Muricopsis*" *laccopoia* Gardner. Jung, 1965, Bulls. Amer. Paleontology, v. 49, no. 233, p. 524.

*Diagnosis*: "Shell rather small, biconic. Aperture more than half as long as the entire shell. Spire obscurely scalariform, the posterior ramp broken by the axial sculpture; whorls probably 7 in number in the perfect adult, regularly and rapidly increasing in diameter. Body relatively large, inflated medially, abruptly constricted into the rather slender pillar. Volutions closely appressed, the posterior margin transgressing at the varices upon the preceding whorl. Suture inconspicuous and irregular. Protoconch rather small, smooth, highly polished, subcylindrical; initial whorl strongly inflated medially, immersed at the tip; succeeding volution also convex, though flattening on the last quarter turn; close of protoconch indicated by a slight thickening of the shell. Axials 6, narrow, elevated, sharply rounded on their summits, equal and equispaced, retractive, the varices continuous, each series performing about half a revolution around the axis of the shell, persistent from the earliest whorl of the conch to the anterior fasciole; intervarical areas broadly concave, wider than the varices excepting on the base of the body whorl, where they wedge out; intervarical depressions deepest toward the posterior suture and to the right of the varix, where a curious little pocket is formed—a character perceptible on the third whorl of the conch and strengthening with the growth of the shell. Spirals coarsely threading the entire conch and equally prominent on the axials and the interaxials; primaries 3 on the whorls of the spire and the medial portion of the body, 3 on the base of the body, and 3 or 4 on the pillar, regular in size and spacing, elevated, obtusely ∧-shaped except on the base of the body and the pillar, where they are less elevated and more rounded; separated for the most part by narrower V-shaped channels, though on the base of the body and the pillar the interspaces are flattened and of approximately the same

width as the spirals; one and, on the later whorls, 2 secondaries intercalated between the posterior primary and the suture; secondary spirals may also be intercalated on the base of the body and the pillar; the primary outlining the shoulder and one or more body spirals spinose at the intersection with the axials. Pillar formed by the closely appressed, overlapping varices, the anterior fasciole also bearing the record of successive canals, 1 to each varix. Aperture rather narrow, spatulate, obtusely angulated posteriorly. Labrum varicated a little behind the thin crenate margin, lirate within. Labium excavated at the base of the body, heavily glazed, smooth except for a few rugae on the pillar near the entrance to the canal. Anterior canal of approximately the same length as the wider opening behind it; narrow, with parallel, proximate margins. Anterior fasciole arcuate, built up from the extremities of the successive terminal varices." (Gardner, 1947)

Dimensions of holotype: height 18 mm, diameter 9.8 mm.

Holotype: USNM 371880.

Type locality: USGS 2213, one mile below Bailey's Ferry, Chipola River, Calhoun County, Florida (= TU 457).

*Occurrence*: Unknown formation, Chiapas, Mexico; (?) lower Miocene. Chipola Formation and Oak Grove Sand, Florida; (?) late lower Miocene. Shoal River Formation, Florida; middle Miocene.

*Figured specimen*: USNM 645618; height 26 mm, diameter 14 mm; locality TU 458. Other occurrences: TU locality nos. 69A, 91, 196, 456, 457, 546, 554, 655, 709, 787, 810, 817, 825, 827, 830, 831, 950, 998, 999.

*Discussion*: All of the species of *Panamurex* are closely related and at first glance several seem to be identical. But upon examination it can be seen that each of the named forms is a valid species. *P. laccopoia* is most like *P. gatunensis* and *P. clarksvillensis*. Between *P. laccopoia* and *P. gatunensis* the angle of the shoulder is one of the most obvious differences, that of *P. gatunensis* being sloped down so that the shoulder spines point outward. This gives the shell a diamond-shaped outline, but in *P. laccopoia* the shoulder spines turn up and produce a more oval outline. Both species possess a labral tooth but in *P. gatunensis* this tooth is separated from the shoulder spine by four spiral ribs and in *P. laccopoia* it is separated by only three. *P. gatunensis* also attains a larger size. The specimen figured by Woodring (1959, pl. 35, figs. 6, 7), if complete, would measure about 50 mm; the largest specimen seen of *P. laccopoia* is 33 mm. *P. laccopoia* differs from *P. clarksvillensis* in having a much smaller nucleus. The nuclear whorls of *P. clarksvillensis* are approximately 1 mm in diameter and those of *P. laccopoia* are about

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PLATE 4

Figures Page

1-2. *Poirieria (Poirieria) woodsensis* E. H. Vokes, n. sp. ---------- 17

1. (× 2) ANSP 7059 (holotype); height 23 mm, diameter 16 mm.
Locality: Woods Bluff, Tombigbee River, Alabama. Hatchetigbee Fm., lower Eocene.

2. (× 1½) ANSP 7059a (paratype); height 37 mm, diameter 28 mm.
Locality: Woods Bluff, Tombigbee River, Alabama. Hatchetigbee Fm., lower Eocene.

3. *Poirieria (Paziella) harrisi* E. H. Vokes, *nom. nov.* (× 3) ---------- 18
ANSP 14225 (holotype-*Murex morulus* Conrad); height 15 mm, diameter (including spines) 11 mm.
Locality: Claiborne Bluff, Alabama River, Alabama. Gosport Sand, middle Eocene.

4. *Poirieria (Paziella) dominicensis* (Gabb) (× 3) ---------- 19
ANSP 3252 (lectotype); height 17.5 mm, diameter 11 mm.
Locality: Dominican Republic. Gurabo Fm., middle Miocene.

5. *Poirieria (Paziella) septima* E. H. Vokes, n. sp. (× 2) ---------- 22
USNM 646429 (holotype); height 33 mm, diameter 17 mm.
Locality: Tuzantepetl, Veracruz, Mexico. Paraje Solo Fm., (?) upper Miocene.

6. *Poirieria (Flexopteron) collata* (Guppy) (× 2) ---------- 26
USNM 115479a (paratype); height 20 mm, diameter 13 mm.
Locality: Bowden, Jamaica. Bowden Fm., (?) upper Miocene.

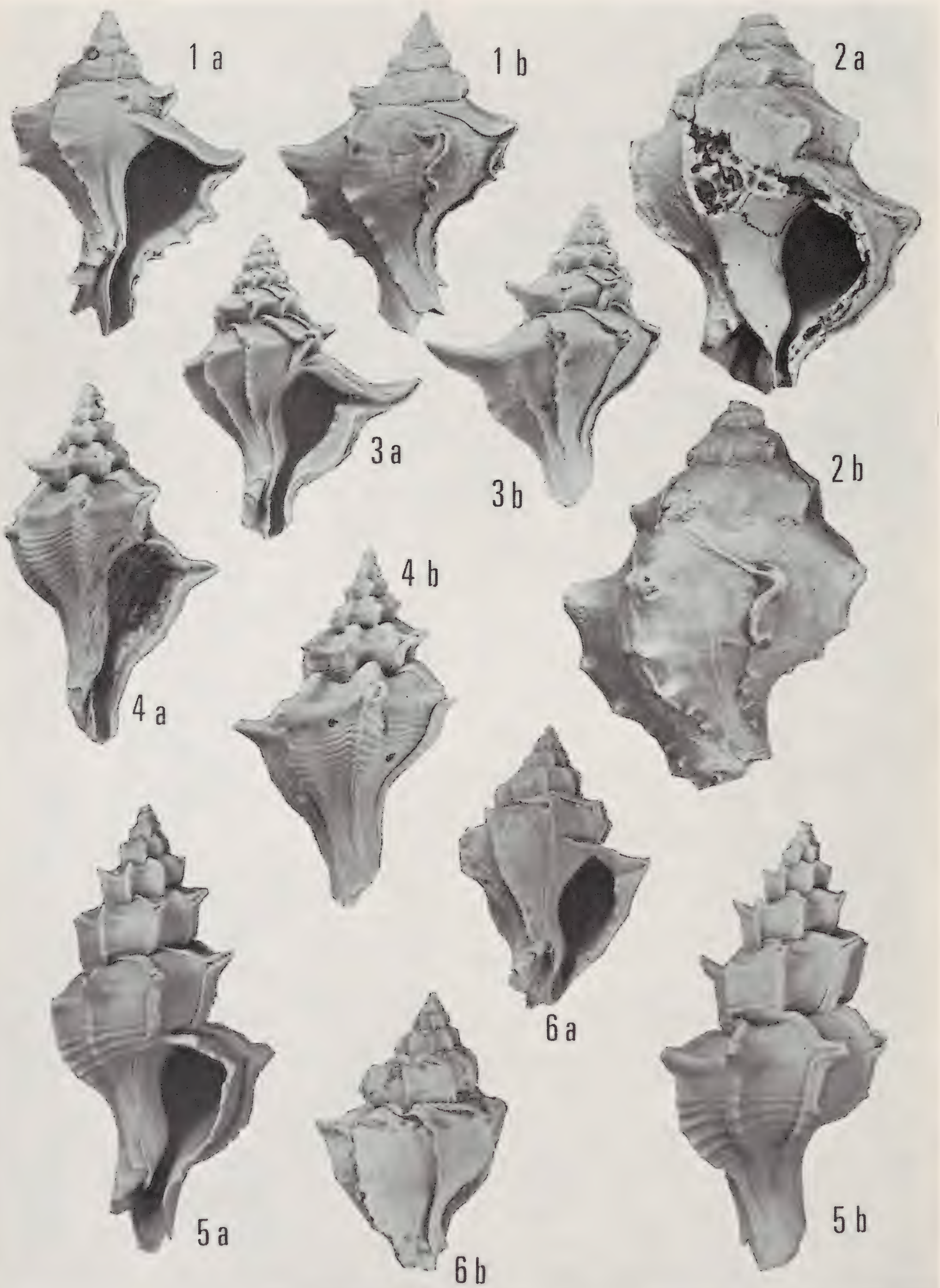


PLATE 4

.4 mm, or less than one-half that of *P. clarksvillensis*. Although Woodring (1959, p. 217) placed *P. laccopoia* in the synonymy of *P. fusinoides* the two species are easily distinguished by the lack of the labral tooth in *P. fusinoides,* by its higher spire and narrower outline, and by the row of spines circling the canal in *P. fusinoides* but lacking in *P. laccapoia.*

*P. laccopoia* is widespread in the Chipola Formation and is represented in the Oak Grove Sand (TU 91) and the Shoal River Formation (TU 69A). Gardner (1947, p. 530) reported the presence of this species in these two formations also but her material was no better than that in the Tulane collection. In the collections of the Museum of Paleontology, University of California, Berkeley, there is a specimen of *P. laccopoia* from San Gregorio, Chiapas, Mexico, said to be lower Miocene in age. With it is a specimen of *Chicoreus* sp., identical to an undescribed Chipola form, and it seems likely that the Chiapas beds are directly correlative with the Chipola. In northeastern Mexico the Guajalote Formation also carries a Chipola fauna (see Gardner, 1945, p. 19-21) suggesting a seaway between the two extreme occurrences.

## Poirieria (Panamurex) fusinoides (Gardner)

Plate 6, figs. 9a, 9b

*Paziella* (*Dallimurex*) *fusinoides* Gardner, 1947, U. S. Geol. Surv. Prof. Paper 142-H, p. 524, pl. 52, figs. 39, 42.

*Paziella* [(*Panamurex*)] *fusinoides* Gardner. Woodring, 1959, U. S. Geol. Surv. Prof. Paper 306-B, p. 217.

[*Poirieria* (*Panamurex*)] *fusinoides* (Gardner). E. H. Vokes, 1964, Malacologia, v. 2, no. 1, p. 18.

*Paziella* (*Dallimurex*) *fusinoides* Gardner. Jung, 1965, Bulls. Amer. Paleontology, v. 49, no. 223, p. 524.

*Diagnosis*: "Shell large and heavy, for the group; fusiform. Aperture about half as long as the entire shell. Whorls of conch probably 8 or 9, regularly increasing in diameter, the early volutions obscurely shouldered, the outline of the later volutions largely determined by the broad and prominent costals. Body whorl inflated, very abruptly constricted into the slender pillar. Sutures inconspicuous, evenly undulated by the costals of the preceding volution. Protoconch like that of *Paziella* (*Dallimurex*) *lychnia*, small, smooth, twice-coiled, the initial turn inflated, immersed at the tip, the succeeding whorl well-rounded, flattening toward its close; dividing line between conch and protoconch indicated by a narrow riblike thickening of the shell and by the initiation of the sculpture. Axials on the early volutions narrow but smoothly rounded, feebly retractive, 6 or 7 in number, equisized and equispaced, uniform in elevation from the periphery to the anterior suture but dying out on the ill-defined shoulder; outer margin of the shoulder coronated with short, sharp spines formed by the intersection of the axials with the peripheral spiral. Axials on the later volutions prominent, broadly rounded, varicose but undulatory in character, disappearing rather abruptly a little in front of the posterior suture, thus forming an obscure shoulder; axials persisting, however, to the anterior suture and well down to the base of the body and appearing on the pillar as closely appressed, overlapping folds; component laminae of the varices occasionally free, visible only on the apertural side of the varix and only on the later volutions; sharply frilled by the spirals but not produced into spines except on the shoulder and the medial portion of the pillar; intervarical areas concave and of approximately the same width as the varices. Spiral threading sharp; lirae narrow, elevated, angular, the primaries 3 in number on the early whorls, 4 or 5 on the penultima and antepenultima, and 7 to 9 on the body exclusive of the pillar, separated by flattened interspaces approximately double the width of the spirals; posterior primary outlining the periphery and forming the midrib of the short, varical spines; 1 or, on the later whorls, 2 threadlets intercalated between the periphery and the suture line and undulated in harmony with the suture; a secondary regularly intercalated between the peripheral spiral and the spiral next in front of it; 1 or 2 finer spirals at the extreme base of the body; pillar girded with 3 simple primaries, a series of short spines —one to each varix—parallel to the primaries, and 1 or 2 irregular spirals in front of the spines. Anterior fasciole sharply rounded, laminated by the extremities of the varices, not spirally threaded. Aperture spatulate, oblique, broadest posteriorly, not sulcated at the posterior commissure. Outer lip arcuate, varicated behind the margin, thin and sharply crenate at the margin in harmony with the spirals, lirate within, the lirae usually short and corresponding in position to the interprimary areas. Inner wall of aperture excavated at the base of the body, smoothly and heavily glazed. Pillar moderately long and straight, corrugated just behind the entrance to the canal, with 3 to 6 lirations at right angles to the axis. Anterior canal long and slender, the margins proximate and parallel. Anterior fasciole diverging slightly, leaving a narrow, umbilical chink between the fasciole and the inner margin of the canal." (Gardner, 1947)

Dimensions of holotype: height 36.7 mm, diameter 16.5 mm.

Holotype: USNM 371854.

Type locality: USGS 2564, one mile below Bailey's Ferry, Chipola River, Calhoun County, Florida (= TU 457).

*Occurrence*: Chipola Formation, Florida; (?) late lower Miocene.

*Figured specimen*: USNM 645619; height 39.4 mm, diameter 27.8; locality TU 951. Other occurrences: TU locality nos. 70, 196, 456, 457, 458, 546, 554, 655, 708, 709, 710, 787, 817, 825, 827, 830, 831, 950, 998.

*Discussion*: *P. fusinoides* is common in the Chipola Formation but it is usually found at localities along Ten Mile Creek rather than those on the Chipola River and Farley Creek to the east. This species occurs together with *P. laccopoia* but the two forms are easily separated by the lack of a labral tooth in *P. fusinoides* and by the presence of a row of spines circling the base of the siphonal canal in *P. fusinoides*, which is not seen in *P. laccopoia*. *P. fusinoides* also has a more elevated spire than *P. laccopoia*, a more slender outline, and is a much larger species. The largest specimen seen of *P. fusinoides* (TU 950) measures 45 mm in height, the largest specimen of *P. laccopoia* (TU 456) is less than 35 mm in height.

## Poirieria (Panamurex) lychnia (Gardner)

Plate 6, figs. 5a, 5b

*Muricidea spinulosa* Heilprin. Dall, 1890, Wagner Free Inst. Sci., Trans., v. 3, pt. 1, p. 149; Dall, 1903, *ibid.*, v. 3, pt. 6, p. 1577 (*not* of Heilprin).

*Paziella* (*Dallimurex*) *lychnia* Gardner, 1947, U. S. Geol. Surv. Prof. Paper 142-H, p. 523, pl. 53, figs. 12, 13.

*Paziella* (*Dallimurex*) *lychnia* Gardner. Woodring, 1959, U. S. Geol. Surv. Prof. Paper 306-B, p. 217.

[*Poirieria* (*Panamurex*)] *lychnia* (Gardner). E. H. Vokes, 1964, Malacologia, v. 2, no. 1, p. 18.

*Diagnosis*: "Shell of moderate dimensions for the group, rather slender, fusiform, hexagonal. Aperture decidedly more than half as long as the entire shell. Spire elevated, scalar; the rapidly tapering whorls acutely angulated at the periphery; the broad shoulder ramp not far from horizontal, undulated by the varices and slightly concave at the varical spines; the sides of the whorls nearly vertical. Body whorl rounded medially, obliquely constricted into the rather slender pillar. Number of whorls at least 6 and possibly 7 in the perfect adult; coiling very close, the posterior margin creeping up a little on the preceding whorl. Sutures inconspicuous, irregular. Protoconch small, smooth, polished, twice coiled, the initial turn inflated, immersed at the tip, the succeeding volution also well-rounded though flattening somewhat toward its close. Dividing line between conch and protoconch indicated by a slight thickening of the shell and by the abrupt initiation of the axial sculpture. Varices 6, equisized and equispaced, terminating at the peripheral angle in a slender spine curved upward and backward; a single row of spines also girding the pillar; free edges of varical lamellae on the body fluted by the primaries; intervarical areas smoothly concave; varices obsolete on the shoulder except for the closely appressed, overlapping, retractive laminae. Spiral sculpture restricted to low, rounded, equisized and equispaced lirations, 2 or 3 on the whorls of the spire, the posterior liration outlining the periphery, the anterior almost or entirely concealed by the suture, the medial midway between the suture and the periphery; spirals 6 to 8 on the body, even and regular from the periphery to the base; secondaries not intercalated; sculpture on the pillar restricted to the single row of varical spines, without a connecting spiral, girding the pillar midway between the base of the body and the anterior fasciole. Fasciole corrugated by heavy, overlapping lamellae, one to each varix. Aperture narrowly elliptical, exclusive of the canal, which is a little less than half as long as the entire opening; aperture obscurely sulcated at the commissure, emarginate at the periphery. Labrum broadly arcuate in front of the periphery, varicated a little behind the margin, finely crenate at the margin in harmony with the spiral sculpture, lirate within; the lirae corresponding roughly in position to the interspiral areas, tending to alternate in length, the longer of the lirations produced far within the aperture. Labium concave, smoothly and heavily glazed, the margin detached from the pillar wall. Anterior canal compressed, with narrow, proximate margins. Anterior fasciole well differentiated, emarginate at its extremity, flaring away from the labial margin, leaving a narrow cuneate umbilical opening." (Gardner, 1947)

Dimensions of holotype: height 25.5 mm, diameter 15 mm.

Holotype: USNM 371853.

Type locality: USGS 2213, one mile below Bailey's Ferry, Chipola River, Calhoun County, Florida (= TU 457).

*Occurrence*: Chipola Formation, Florida; (?) late lower Miocene.

*Figured specimen*: USNM 645617; height 20 mm, diameter 11 mm; locality TU 547. Other occurrences: TU locality nos. 457, 458, 546, 554, 555, 817, 950.

*Discussion*: *P. lychnia* is the least common of the Chipola species of *Panamurex*. It is easily confused with the following species, *P. mauryae* E. H. Vokes, which is a smaller, less foliaceous form. *P. lychnia* is very close to the Recent *P. carnicolor*, the

only difference being that the siphonal canal of *P. carnicolor* is more sharply constricted at the base of the body whorl and the body whorl is somewhat more inflated. *P. carnicolor* is slightly more spinose than *P. lychnia*, with spines being developed on the varices other than just at the shoulder.

The depth range for *P. carnicolor* (from 50 to 162 fathoms) indicates that it is a deeper water species than is usually encountered in the fossil record. *P. lychnia* may have also been a somewhat deeper species, explaining its relative scarcity in the Chipola beds.

### Poirieria (Panamurex) mauryae
E. H. Vokes, n. sp.

Plate 6, figs. 8a, 8b

*Diagnosis*: Shell small for the group, nucleus of one and one-half somewhat flattened whorls; six post-nuclear whorls in adult. Axial ornamentation of ten small simple varices on first post-nuclear whorl, gradually decreasing to six varices on body whorl of adult. Varices low, rounded, marked only by a small open spine at the shoulder, almost obsolete on remainder of shell. Spiral ornamentation of two major ribs with smaller intercalary threads on early whorls, six to eight on the body whorl, depending upon the strength of the intercalaries. One spiral rib on siphonal canal, giving rise to small open spines at the varices. Axial growth lines producing a scabrous texture covering the entire shell surface. Suture greatly appressed, sinuous, riding up over the varices and down into the intervarical areas. Aperture ovate, outer lip thickened, bearing within about seven greatly elongated spiral ridges, which approximate the areas between the exterior spiral ribs. Inner lip marked by four small denticulations, separated into two pairs, at the abapical end and one tooth at the adapical end. Siphonal canal short, open, recurved at distal end; terminations of previous canals forming a small false umbilicus.

Dimensions of holotype: height 16.6 mm, diameter 9 mm.

Holotype: USNM 646431.

Type locality: TU 458, east bank of Chipola River, just above mouth of Farley Creek (SW ¼ Sec. 20, T1N, R9W), Calhoun County, Florida.

*Occurrence*: Chipola Formation, Florida; (?) late lower Miocene.

*Figured specimen*: USNM 646431 (holotype). Other occurrences: TU locality nos. 453, 456, 457, 546, 547, 554, 555, 655, 817, 818, 820b, 821, 825, 827, 828, 830, 950, 951, 998, 999.

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## Plate 5

Figures — Page

1. *Poirieria (Paziella) pazi* (Crosse) (× 1½) ..... 22
   USNM 678944; height 39 mm, diameter (excluding spines) 19 mm.
   Locality: *Silver Bay* Station 2481, off Hollywood, Florida, 200 fms. Recent.
2. *Poirieria (Paziella) atlantis* (Clench and Pérez Farfante) (× 2) ..... 23
   MCZ 164684 (holotype); height 23.4 mm, diameter (excluding spines) 10.5 mm.
   Locality: *Atlantis* Station 3333, Bahía de Cochinos, Cuba, 190-200 fms. Recent.
3. *Poirieria (Paziella) oregonia* (Bullis) (× 1) ..... 26
   USNM 635149 (holotype); height 85.2 mm, diameter (excluding spines) 37.8 mm.
   Locality: *Oregon* Station 2023, off French Guiana, 135 fms. Recent.
4. *Poirieria (Paziella) nuttingi* (Dall) (× 1½) ..... 24
   USNM 107372 (holotype); height 44.4 mm, diameter (excluding spines) 20.5 mm.
   Locality: Off Sand Key, Florida, 15 fms. Recent.
5. *Poirieria (Pazinotus) bowdenensis* E. H. Vokes, n. sp. (× 4) ..... 27
   USNM 369621 (holotype); height 13.5 mm, diameter 7 mm.
   Locality: Bowden, Jamaica. Bowden Fm., (?) upper Miocene.
6-7. *Poirieria (Pazinotus) stimpsonii* (Dall) (× 4) ..... 28
   6. USNM 87087 (lectotype); height 12 mm, diameter 7 mm.
      Locality: Off Barbados, B. W. I., 100 fms. Recent.
   7. MCZ 7310 (lectoparatype); height 11 mm, diameter 7.4 mm.
      Locality: Off Barbados, B. W. I., 100 fms. Recent.

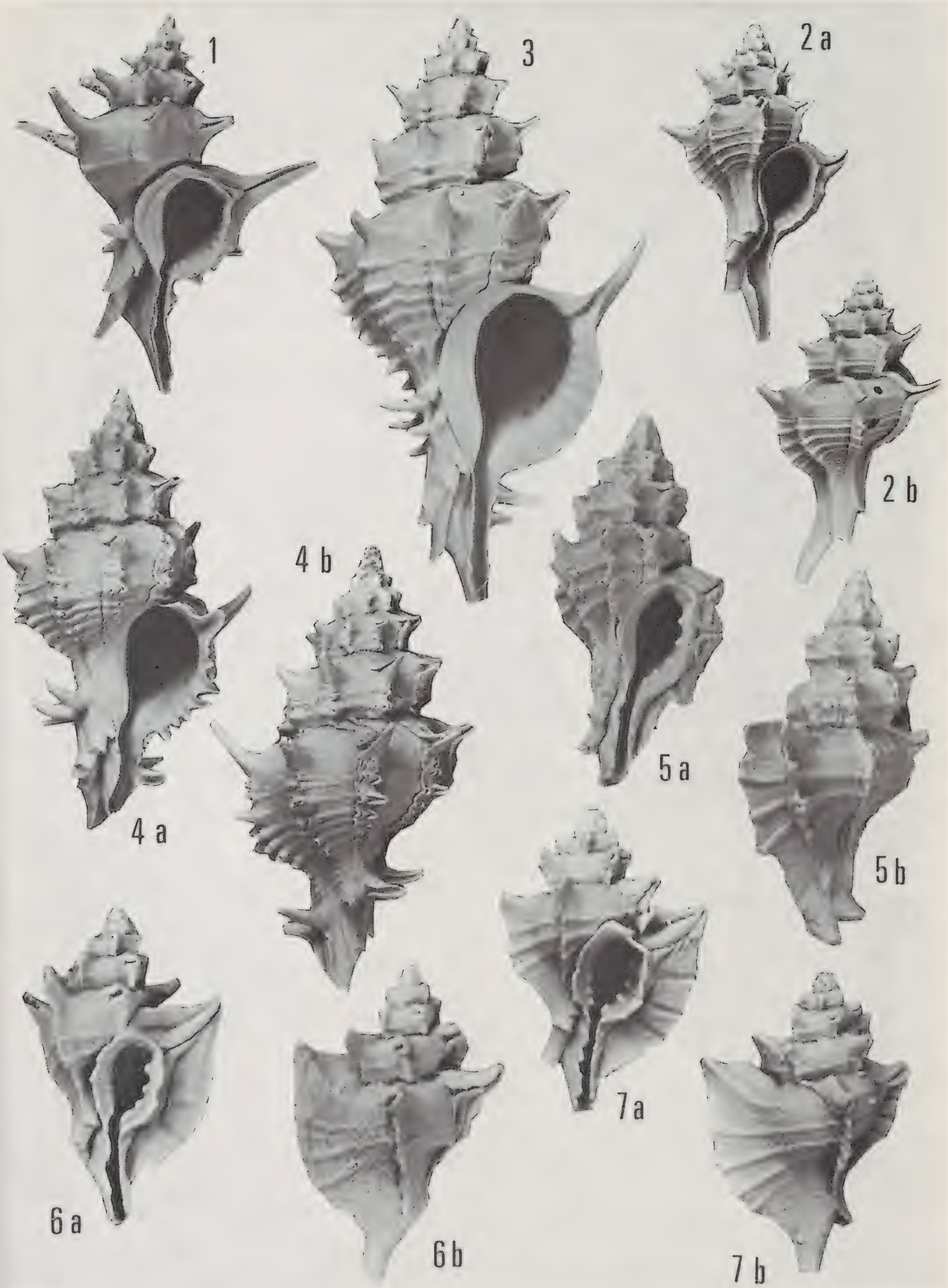


PLATE 5

*Discussion*: *P. mauryae* is one of the commoner Chipola muricid species, especially in the calcaranite facies of Farley Creek and the Chipola River, but may be easily taken for an abraded specimen of *P. lychnia*. However, it is consistant in its differences from *P. lychnia*, having a smaller, less spinose shell, which is more globose in outline. The largest specimen seen of *P. mauryae* (from TU 951) measures only 20 mm in height with the average size about 15-17 mm, but *P. lychnia* may exceed 30 mm. *P. mauryae* possesses only minute spines, if any, and those only at the shoulder and canal. *P. lychnia* has long spines at shoulder and canal with numerous smaller spines on the varices between the two rows of major spines.

This new species is unquestionably ancestral to *P.* (*P.*) *velero* Vokes, n. sp., discussed below (see Text fig. 1). The two forms are distinguishable by the heavier spiral ornamentation in the Recent species. Also, the angle of the shoulder is more sloping in the fossil shell and the area between the suture and the shoulder spiral is almost smooth, while it is strongly ornamented in the Recent species. The body whorl of *P. mauryae* is somewhat more inflated than that of *P. velero*. Nevertheless, the two forms are strikingly similar and seem to have had identical ecologic requirements. *P.* (*Panamurex*) *mauryae* is most common at the Chipola localities along Farley Creek and the lower Chipola River, where the evidence suggests shallow open water, with corals and reef-dwelling pelecypods, such as *Spondylus* and *Chama*, in great numbers. Abundant miliolids and dasycladacean algae further confirm this diagnosis.

*P. mauryae* is also closely related to the Oak Grove species named "*Urosalpinx*" *phagon* Gardner, which follows. *P. phagon* is even less spinose, having no spines whatsoever. *P. phagon* is a larger species than *P. mauryae*, both of the specimens figured here (pl. 6, figs. 7 & 8) have six post-nuclear whorls but *P. phagon* is noticeably larger. This species is very rare, there being known but the two specimens in the type lot and a third here figured, so far as the writer is aware. It is possible that *P. mauryae* may prove to be only an ecologic variety of *P. phagon* but without more material the writer prefers to keep the two forms distinct.

Jung (1969, p. 494, pl. 50, figs. 7-9) has recently named a species from the upper Miocene Melajo Clay of Trinidad that is not unlike *P. mauryae*. This species, assigned by Jung to the genus *Calotrophon* with a query, seems to be intermediate between *P. mauryae* and *Pseudosalpinx floridana* (Conrad). *Calotrophon* (?) *hutchisoni*, as it was named by Jung, differs from both the typical *Calotrophon* and from *Pseudosalpinx* in having four marked denticles near the anterior end of the parietal callus and for this reason the species is here referred to *Panamurex*.

### Poirieria (Panamurex) phagon (Gardner)

Plate 6, figs. 7a, 7b

*Urosalpinx phagon* Gardner, 1947, U. S. Geol. Surv. Prof. Paper 147-H, p. 530, pl. 52, figs. 36, 37.

*Diagnosis*: "Shell rather small, solid, fusiform in outline, the maximum diameter falling not far from the median horizontal. Spire turreted, the whorls increasing regularly and rather rapidly in diameter. Whorls of conch 5 in number, closely appressed, the posterior margin creeping up a little upon the preceding volution. Shoulder very broad and rather steeply sloping, the periphery of the whorls of the spire falling in front of the median horizontal. Sides of whorls approximately parallel to the axis. Body obliquely constricted at the base into the moderately long and slender pillar. Sutures inconspicuous, undulated by the costals of the preceding whorl. Protoconch small, smooth, twice-coiled, the initial turn moderately inflated but flattened behind and immersed at the tip; final whorl convex, flattening on the last half turn; close of protoconch indicated by a slight rib-like thickening of the shell. Axials prominently elevated, running in the holotype 8 to the whorl from the initial turn of the conch to the body, very narrow and sharply rounded upon the posterior volutions, broad and somewhat undulatory in character upon the anterior, uniform in prominence from the periphery to the anterior suture but weakening upon the shoulder; body axials most prominent upon the periphery, more or less obsolete upon the base; intercostal areas concave and usually a little narrower than the costals. Entire surface shagreened with fine incremental laminae, most prominent upon the shoulder, where the fine, sharp edges rasp the surface almost as strongly as in *Coralliophaga* [? *Coralliophila*]. Spiral sculpture subdued; primaries low, rounded, equal and regularly spaced, 2 or 3 in number upon the whorls of

the spire, 6 upon the medial portion of the body; 3 upon the base of the body, and 4 or 5 upon the pillar; posterior spiral outlining the periphery; shoulder free from threading; secondaries fortuitously introduced between the primaries, most frequently upon the body. Anterior fasciole arched and corrugated by the axials but not spirally lirate. Aperture moderately wide, oblique, acutely angulated at the posterior commissure. Outer lip obtusely angulated at the shoulder, obliquely constricted at the base of the body, varicated a little behind the margin, lirate within, the lirae produced far within the aperture and corresponding in position to the spaces between the primaries. Labium excavated at the base of the body, rather heavily and very smoothly glazed, the pillar feebly rugose in the adult; inner margin of pillar sharply rounded at the entrance to the anterior canal. Canal moderately long, bent backward slightly, the margins parallel and proximate. Anterior extremity broadly emarginate. Umbilicus imperforate in the young, the fasciole flaring in the adult so that a narrow chink is left between the fasciole and the inner wall of the canal." (Gardner, 1947)

Dimensions of holotype: height 16.5 mm, diameter 9.2 mm.

Holotype: USNM 371856.

Type locality: Oak Grove, Okaloosa County, Florida (= TU 91).

*Occurrence*: Oak Grove Sand, Florida; (?) late lower Miocene.

*Figured specimen*: USNM 646430 (topotype); height 20 mm, diameter 11.5 mm; locality TU 91.

*Discussion*: Originally assigned to the genus *Urosalpinx* by Gardner this species is better placed with the *Panamurex* group for it possesses the apertural denticulations of that group. The shells of *Urosalpinx* are of a calcitic composition and fossilize with a type of translucence that is characteristic and easily recognized. Shells of *Ecphora* and *Pecten* are perhaps the best examples of this type of shell composition but numerous other groups also possess it to a less striking degree. This transluscence is seen in the other species of *Urosalpinx* named by Gardner from the Oak Grove, *U. xustris*, but not in *P. phagon*.

This species is most closely related to *P. mauryae*, above, and is discussed further there. It is possible that *P. phagon* is a nearshore equivalent of *P. mauryae* but from the limited material of *P. phagon* available the two forms seem to be distinct.

## Poirieria (Panamurex) gabbi
## E. H. Vokes, n. sp.

Plate 7, figs. 2a, 2b

*Diagnosis*: Nucleus unknown, seven post-nuclear whorls in the holotype. Axial ornamentation consisting of eight small varices on each of the first three post-nuclear whorls, decreasing then to seven on each of the succeeding whorls, including the last. Varices bearing small open spines only at the shoulder; where other major spiral ribs cross the varices only small ridges are formed. Spiral ornamentation of two ribs on the spire whorls with an intermediary thread appearing on the penultimate; six major spiral ribs on body whorl with three smaller riblets between that at the shoulder and the suture; a row of spines encircling the extended siphonal canal and one faint spiral rib between body and canal spines. Suture sigmoidal, rising up between varices and bending down at the varices. Aperture broken in holotype but at least three small denticles present at the anterior end of the inner lip. Nature of outer lip unknown but almost certainly denticulated; no labral tooth present. Siphonal canal open, moderately long, slightly recurved.

Dimensions of holotype: height 24.7 mm, diameter 14 mm.

Holotype: USNM 646084.

Type locality: USGS 8544, right bank of Rio Gurabo, about 150 meters above middle ford at Gurabo Adentro, Monte Cristi, Dominican Republic.

*Occurrence*: Gurabo Formation, Dominican Republic; middle Miocene.

*Figured specimen*: USNM 646084 (holotype).

*Discussion*: This new species, based on a unique specimen from the Gurabo Formation of the Dominican Republic, is most closely related to *P. fusinoides* (Gardner) from the Chipola Formation. It differs in having a more inflated shell with less pronounced spiral ornamentation. *P. gabbi* also has one less spiral rib than *P. fusinoides*, which has three such ribs on the spire whorls. The spiral threads between the major spiral rib at the shoulder and the suture are stronger in *P. fusinoides* than in *P. gabbi* as are the spiral riblets between the body and the row of encircling spines on the siphonal canal. The canal is shorter in *P. gabbi* and the varices are less scabrous.

Woodring (1959, p. 218) compared this species to *P. gatunensis* from the Gatun Formation of Panamá and noted that it differs from the latter in being more slender and not so strongly sculptured. The two species also differ in the labral tooth seen in *P.*

*gatunensis* but lacking in *P. gabbi*, as well as the spines on the siphonal canal seen in *P. gabbi* and lacking in *P. gatunensis*.

### Poirieria (Panamurex) gatunensis (Brown and Pilsbry)

Plate 7, figs. 6a, 6b

*Murex* (*Phyllonotus*) *gatunensis* Brown and Pilsbry, 1911, Acad. Nat. Sci. Phila., Proc., v. 63, p. 354, pl. 26, fig. 2; Brown and Pilsbry, 1913, *ibid.*, v. 64, p. 503.

*Murex gatunensis* Brown and Pilsbry. Pilsbry and Brown, 1917, Acad. Nat. Sci. Phila., Proc., v. 69, p. 34.

*Murex* (*Phyllonotus*) *gatunensis* Brown and Pilsbry. Vaughan, 1919, U. S. Natl. Mus., Bull. 103, p. 558, 561.

*Paziella* (*Panamurex*) *gatunensis* Brown and Pilsbry. Woodring, 1959, U. S. Geol. Surv. Prof. Paper 306-B, p. 150, 151, 152, 217, pl. 35, figs. 6, 7, 9, 10.

[*Poirieria* (*Panamurex*)] *gatunensis* (Brown and Pilsbry). E. H. Vokes, 1964, Malacologia, v. 1, no. 2, p. 18, pl. 2, fig. 32.

*Paziella* (*Panamurex*?) cf. *gatunensis* (Brown and Pilsbry). Jung, 1965, Bulls. Amer. Paleontology, v. 49, no. 223, p. 523, pl. 69, figs. 11, 12.

*Diagnosis*: "The shell resembles *M. spinulosa* in general form. Embryonic whorls unknown; subsequent whorls about 6, strongly convex, subangular at the shoulder, the last contracted into a narrow but short anterior canal. Sculpture: on the last whorl seven strong varices, each with a short horizontal spine at the shoulder and about half as wide as the intervals; sharp, narrow, unequal spiral ridges over both varices and intervals. These ridges are unequally spaced, and the concave interstices bear numerous weak spiral striae. On the penultimate whorl, two ridges are visible below, and two or three above the shoulder-angle. The aperture is triangular-ovate; outer lip has 11 or 12 short, acute teeth on the submarginal internal callus." (Brown and Pilsbry, 1911)

Dimensions of holotype: height (incomplete) 32 mm, diameter 21 mm.

Holotype: ANSP 1720.

Type locality: Gatun Locks excavation, Canal Zone.

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## Plate 6

Figures — Page

1-2. *Poirieria (Panamurex) macneili* E. H. Vokes, *nom. nov.* ..... 30
1. (× 3) USNM 644618 (holotype); height 15.5 mm, diameter 9 mm.
Locality: Byram, Mississippi. Byram Marl, middle Oligocene.
2. (× 2) USNM 646432; height 23.5 mm, diameter 12.3 mm.
Locality: Byram, Mississippi. Byram Marl, middle Oligocene.

3-4. *Poirieria (Panamurex) heilprini* (Cossman) ..... 30
3. (× 2) USNM 165089; height 23.5 mm, diameter 13 mm.
Locality: Ballast Point, Tampa Bay, Florida. Tampa Limestone, lower Miocene.
4. (× 4) USNM 112065; height 10 mm, diameter 7 mm.
Locality: Ballast Point, Tampa Bay, Florida. Tampa Limestone, lower Miocene.

5. *Poirieria (Panamurex) lychnia* (Gardner) (× 2) ..... 35
USNM 645617; height 20 mm, diameter 11 mm.
Locality: TU 547. Chipola Fm., (?) lower Miocene.

6. *Poirieria (Panamurex) carnicolor* (Clench and Pérez Farfante) (× 1½) ..... 46
USNM 679266; height 28 mm, diameter 16 mm.
Locality: *Oregon* Station 5070, off Nevis, Leeward Islands, 50-60 fms. Recent.

7. *Poirieria (Panamurex) phagon* (Gardner) (× 2) ..... 38
USNM 646431 (topotype); height 20 mm, diameter 11.5 mm.
Locality: TU 91. Oak Grove Sand, (?) lower Miocene.

8. *Poirieria (Panamurex) mauryae* E. H. Vokes, n. sp. (× 2) ..... 36
USNM 646430 (holotype); height 16.6 mm, diameter 9 mm.
Locality: TU 458. Chipola Fm., (?) lower Miocene.

9. *Poirieria (Panamurex) fusinoides* (Gardner) (× 1½) ..... 34
USNM 645619; height 39.4 mm, diameter 27.8 mm.
Locality: TU 951. Chipola Fm., (?) lower Miocene.

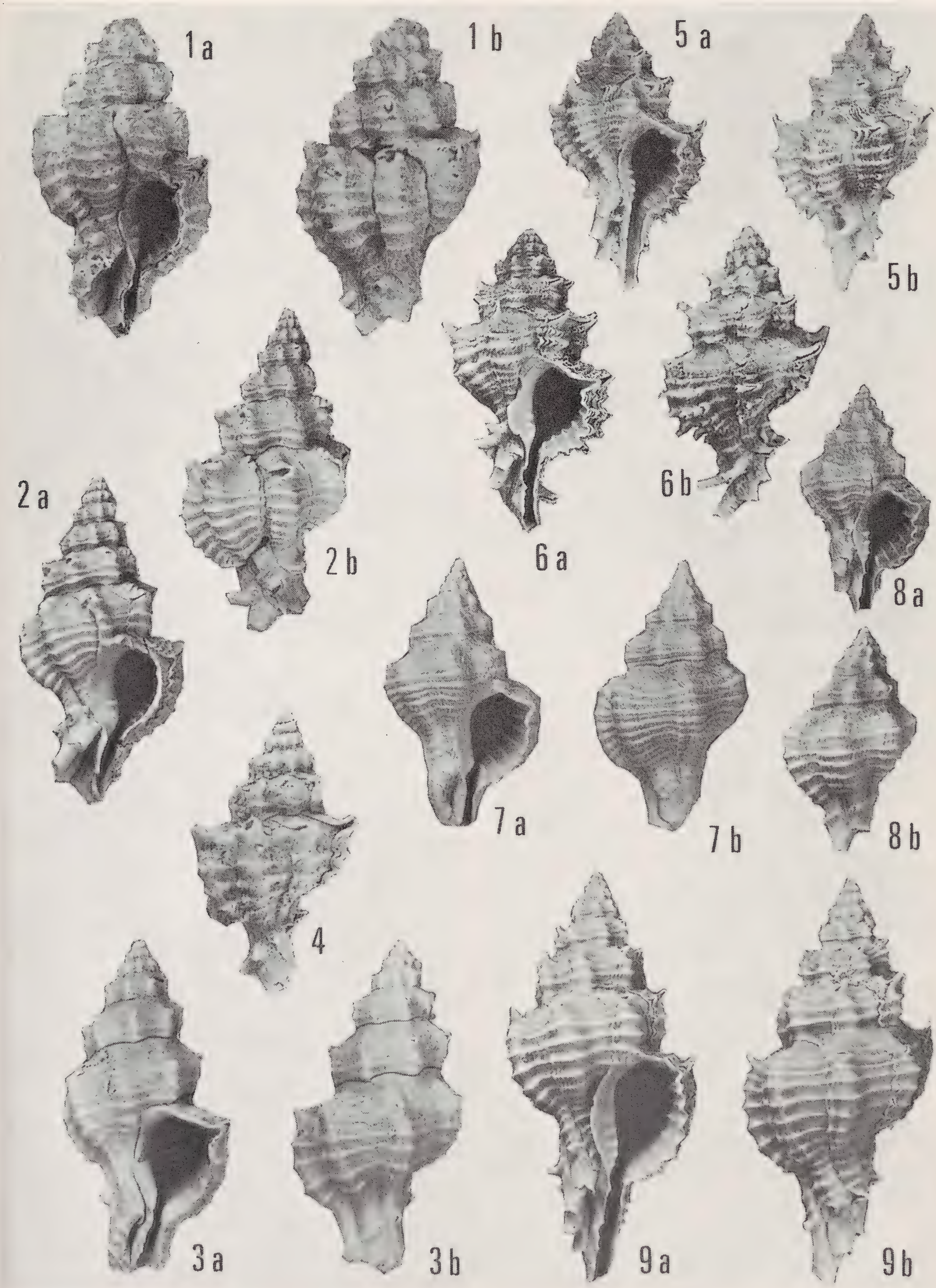


PLATE 6

*Occurrence*: (?) Emperador Limestone, Panamá; lower Miocene. Gatun Formation, Panamá and Colombia; middle Miocene. Unnamed formation, Paraguaná Peninsula, Venezuela; late middle Miocene.

*Figured specimen*: USNM 645620; height 40.8, diameter 26.0 mm; locality TU 958. Other occurrences: TU locality nos. 757, 959.

*Discussion*: Woodring (1959, p. 218) compared *P. gatunensis* with the Chipola species *P. fusinoides*, but as has been discussed above a closer relationship exists between *P. gatunensis* and *P. laccopoia*. This latter species Woodring placed in synonymy with *P. fusinoides* and this is undoubtedly the reason for his comparison. The differences between the three forms are discussed under *P. laccopoia*.

Brown and Pilsbry (1913, p. 503) listed this species from a locality in the lower Miocene Emperador Limestone of Panamá but this occurrence was not verified by Woodring. These same authors (Pilsbry and Brown, 1917, p. 34) also listed *P. gatunensis* from the "Oligocene" (*i.e.*, Gatun) near Cartagena, Columbia. The writer has examined their specimen and it is *P. gatunensis*. There are specimens in the collection of the Museum of Paleontology, University of California, Berkeley, from near Usiacuri, Dept. of Atlantico, Colombia, not far from Cartagena, in beds that are presumed to be Gatun in age. Jung (1965, p. 523, pl. 69, fig. 11, 12) figured a specimen from Venezuela, which he only compared to *P. gatunensis* as it was a juvenile, but it seems to be identical. Thus this species is one of the most widespread of the group ranging from Panamá to Venezuela in middle Miocene beds.

At the time of Woodring's treatment of this species (1959, p. 218), it was relatively uncommon in collections. He noted that the nine extant adult specimens in the USNM collections were all damaged or fragmentary. Since that time a new excavation near Cativa (TU 958) has yielded numerous fine specimens of *P. gatunensis*. The writer and her husband collected over 50 specimens at this site, the largest of which is the one here figured (pl. 7, fig. 6).

### Poirieria (Panamurex) dubitalis E. H. Vokes, n. sp.

Plate 7, figs. 5a, 5b

*Diagnosis*: Shell large; nature of early whorls unknown, probably seven post-nuclear whorls in adult. Spiral ornamentation on spire whorls of one strong rib at the shoulder, flanked by two smaller ribs on either side. On the body whorl between the strong shoulder rib and the suture three smaller ribs present; on remainder of body whorl six moderately strong spiral ribs with numerous smaller riblets on the extended siphonal canal. Axial ornamentation of six varices on each whorl. Where the shoulder rib crosses the varices one sharp, pointed spine is produced, directed outward from the axis of the shell; at the juncture of the body whorl and the siphonal canal, where the sixth rib anterior to the shoulder crosses the varices a marked labral tooth is developed. Aperture circular, outer lip flaring, with eight small denticulations corresponding to the spaces between the spiral ribs. Inner lip smooth in the holotype but probably with small denticulations usually. Siphonal canal short, broad, succession of previous canals forming a large false umbilicus.

Dimensions of holotype: height 36 mm, diameter (including spines) 27.5 mm.

Holotype: U. N. A. M. Instituto de Geología, Museo Paleontología Invertebrados no. IGM 2187.

Type locality: (?) Tuxtepec, Oaxaca, Mexico.

*Occurrence*: (?) Agueguexquite Formation, Mexico; upper Miocene.

*Figured specimen*: IGM 2187 (holotype).

*Discussion*: In the collections of the Instituto de Geología, Universidad de Mexico (U. N. A. M.), there is a single specimen said to be from Tuxtepec, that seems intermediate between *P. gatunensis* and the next species, *P. alaquaensis*. The shoulder spines point outward in the manner of *P. gatunensis* but the inflated body whorl and heavy ornamentation are more akin to *P. alaquaensis*. There is a large labral tooth present at the base of the body whorl.

The writer visited the Tuxtepec area and an effort was made to locate the spot from whence came this material. A number of localities were found with fossils that correspond to the material described from the region by Böse (1906), now referred to the Concepción Formation, but nowhere was any material seen that matched the species or the preservation of the shell described here. In the same lot of material at the U. N. A. M. there were two specimens of *Typhis carmenae* Gertman (1969, p. 166, pl. 5, fig. 4), which was described from the Agueguexquite Formation. Thus there appears to be little doubt of the Agueguexquite age of this shell but

there does seem to be some considerable doubt as to the locality. The writer strongly suspects that the material did not come from Tuxtepec but rather from somewhere in the Isthmus of Tehuantepec, near Coatzacoalcos.

### Poirieria (Panamurex) alaquaensis (Mansfield)

Plate 7, figs. 3, 4a, 4b

*Muricidea*? *alaquaensis* Mansfield, 1935, Florida Geol. Surv., Bull. 12, p. 39, pl. 3, fig. 9 (holotype); pl. 4, fig. 10 (paratype).

"*Muricidea*?" *alaquaensis* Mansfield. Jung, 1965, Bulls. Amer. Paleontology, v. 49, no. 223, p. 524.

*Diagnosis*: "Shell small, spire about one-third length of body whorl, axial sculpture stronger than spiral, about 1½ nuclear and 5 post-nuclear whorls. Whorls tabulated in front of the suture. Axial sculpture consists of 6 strong ribs extending from suture to suture on the spire whorls and across the canal on the body whorl. These axials are retractive over the tabulated area and nearly vertical below the periphery and when unbroken bear reflected hollow spines at the periphery on the later whorls. The earliest post-nuclear whorls do not bear spines. Spiral sculpture (on spire 3 and on body 12) of primary cords overrunning axials and interspaces. A medial secondary spiral is present on the body whorl. In addition to the primary and secondary ornamentation, tertiary threadlets are visible on most of the shell. Aperture ovate, widest above. Anterior canal rather long, nearly closed and curved backward and to the right. Outer lip within marked with 9 rather short raised spiral lirations, the posterior liration being larger, more widely spaced, and situated near the center of the posterior area of the aperture. Inner lip with a thin callus, bearing 3 lirations at the anterior third. Anterior canal moderately long and nearly closed. Siphonal fasciole strong and ornamented with lamellae." (Mansfield, 1935)

Dimensions of holotype: height 15 mm, diameter 9 mm.

Holotype: USNM 373148.

Type locality: USGS 12046, Vaughan Creek, about three miles from its junction with Alaqua Creek, about 6½ miles nearly south of De-Funiak Springs, Walton County, Florida.

*Occurrence*: Choctawhatchee Formation; Florida; Agueguexquite Formation, Veracruz, Mexico; upper Miocene. Concepción Formation, Veracruz, Mexico; (?) upper Miocene.

*Figured specimens*: Fig. 3, USNM 373148 (holotype). Fig. 4, Univ. California, Museum of Paleontology no. 15978, height 22 mm, diameter 14 mm; locality, Teapa, Veracruz, Mexico. Other occurrences: TU locality no. 638.

*Discussion*: Mansfield knew this species only from the type locality, but in the collections of the Museum of Paleontology, University of California, Berkeley, there is a fine specimen from Teapa, in southern Veracruz, and the writer has collected a worn specimen from the Agueguexquite Formation of the same area (TU 638). The stratigraphic position of the Teapa shell is not known but it is probably from the Concepción Formation (? = TU locality 1025) of (?) upper Miocene age. The Agueguexquite specimen is badly rolled and could well be a reworked shell, as many examples at the same locality would appear to be, for the Concepción Formation underlies the Agueguexquite in this area. Geographically the two occurrences are only about five miles apart but the associated faunas are so different that they are not thought to be correlative in age.

It is unfortunate that both specimens in the type lot are juvenile but the Mexican shells are adult and from them a better understanding of the species is made possible. *P. alaquaensis* is closely related to the older *P. laccopoia* but differs from it in having a much less sloping shoulder. The suture in *P. alaquaensis* is deeply recessed forming pits between the varices. The body whorl of *P. alaquaensis* is more inflated than *P. laccopoia* and the spire is lower, giving the shell a rotund appearance.

There are two specimens in the type lot of *P. alaquaensis* and in his description Mansfield cited these as "cotypes." However, in the plate description he named the larger specimen as holotype and the smaller paratype so that there is no necessity to select a lectotype.

### Poirieria (Panamurex) clarksvillensis (Mansfield)

Plate 7, figs. 7a, 7b

*Muricidea clarksvillensis* Mansfield, 1937, Jour. Paleontology, v. 11, no. 7, p. 610, pl. 85, fig. 6.

*Murex* (*Panamurex*) *clarksvillensis* (Mansfield). E. H. Vokes, 1963, Tulane Stud. Geol., v. 1, no. 4, p. 161, pl. 2, figs. 2a, 2b.

[*Poirieria* (*Panamurex*)] *clarksvillensis* (Mansfield). E. H. Vokes, 1964, Malacologia, v. 2, no. 1, p. 18.

"*Muricidea*" *clarksvillensis* Mansfield. Jung, 1965, Bulls. Amer. Paleontology, v. 49, no. 223, p. 524.

*Diagnosis*: "Shell of moderate size; solid; spire about one-third length of shell; axial sculpture stronger than spiral; consisting of 5 whorls, nucleus decollated. Whorls rounded, weakly tabulated in front of the rather deep suture and rapidly and uniformly expanding. Spiral sculpture consisting of rather strong primary threads (13 on body whorl and canal) over-running axials and interspaces and usually of a secondary intermediate threadlet. Ribs 6, extending from suture to suture on the spire whorls and to the end of the canal on the body whorl. Aperture axially ovate. Outer lip within provided with 8 widely spaced spiral lirations. Inner lip with a thin callus and bearing on its anterior third 3 lirations. Canal rather short and recurved; the raised margin of the canal and the siphonal fasciole separated by a small chink." (Mansfield, 1937)

Dimensions of holotype: height 30 mm, diameter 17 mm.

Holotype: USNM 496424.

Type locality: Four Mile Creek, one half mile northwest of Clarksville, Calhoun County, Florida (= TU 73).

*Occurrence*: Jackson Bluff Formation and Pinecrest Beds, Florida; upper Miocene.

*Figured specimen*: USNM 644378; height 31.4 mm, diameter 15 mm; locality TU 60. Other occurrences: TU locality nos. 72, 797.

*Discussion*: *P. clarksvillensis* is moderately common at Jackson Bluff, Florida (TU 60), but is rare elsewhere. The type locality is near Clarksville, Calhoun County, Florida (TU 73), however no specimens have been taken there by the writer. One specimen has been found in the upper Miocene Pinecrest Beds of southern Florida (TU 797) but this is the only known example outside of the Jackson Bluff Formation.

### Poirieria (Panamurex) hutchisoni (Jung)

*Calotrophon* (?) *hutchisoni* Jung, 1969, Bulls. Amer. Paleontology, v. 55, no. 247, p. 494, pl. 50, figs. 7-9.

*Diagnosis*: "Shell small, solid. Protoconch consists of 1½ whorls, its last part with a basal angulation. Postnuclear whorls a little more than five. Sculpture starting abruptly, consists of nine axials on early, but of seven on late whorls. Axials usually with a short vaulted spine on the shoulder of the whorls. There are two to four weak spirals above the shoulder, and two stronger ones below. Axials not persistent from suture to suture. Body whorls with numerous spirals below the shoulder; its axials usually reaching down to the prominent siphonal fasciole. Outer lip lirate within, its edge crenulated. Callus of inner lip prominent, with four elongate denticles near the base. Anterior canal short, slightly recurved." (Jung, 1969)

Dimensions of holotype: height 16.6 mm, diameter 9.4 mm.

Holotype: USNM 645494.

Type locality: Melajo River area, west of Matura Bay, Trinidad.

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## Plate 7

Figures — Page

1. *Poirieria (Panamurex) laccopoia* (Gardner) (× 2) ---- 31
   USNM 645618; height 26 mm, diameter 14 mm.
   Locality: TU 458. Chipola Fm., (?) lower Miocene.
2. *Poirieria (Panamurex) gabbi* E. H. Vokes, n. sp. (× 2) ---- 39
   USNM 646048 (holotype); height 24.5 mm, diameter 14.3 mm.
   Locality: Rio Gurabo, Dominican Republic. Gurabo Fm., middle Miocene.

3-4. *Poirieria (Panamurex) alaquaensis* (Mansfield) ---- 43
   3. (× 3) USNM 373148 (holotype); height 15 mm, diameter 9 mm.
      Locality: Vaughan Creek, Florida. Choctawhatchee Fm., upper Miocene.
   4. (× 2) UCMP 15978; height 22 mm, diameter 14 mm.
      Locality: Teapa, Veracruz, Mexico. Concepción Fm., (?) upper Miocene.

5. *Poirieria (Panamurex) dubitalis* E. H. Vokes, n. sp. (× 1½) ---- 42
   IGM 2187 (holotype); height 36 mm, diameter 27.5 mm.
   Locality: (?) Tuxtepec, Oaxaca, Mexico. (?) Agueguexquite Fm., upper Miocene.
6. *Poirieria (Panamurex) gatunensis* (Brown and Pilsbry) (× 1½) ---- 40
   USNM 645620; height 40.8 mm, diameter 26 mm.
   Locality: TU 958. Gatun Fm., middle Miocene.
7. *Poirieria (Panamurex) clarksvillensis* (Mansfield) (× 1½) ---- 43
   USNM 644378; height 31.4 mm, diameter 15 mm.
   Locality: TU 60. Jackson Bluff Fm., upper Miocene.

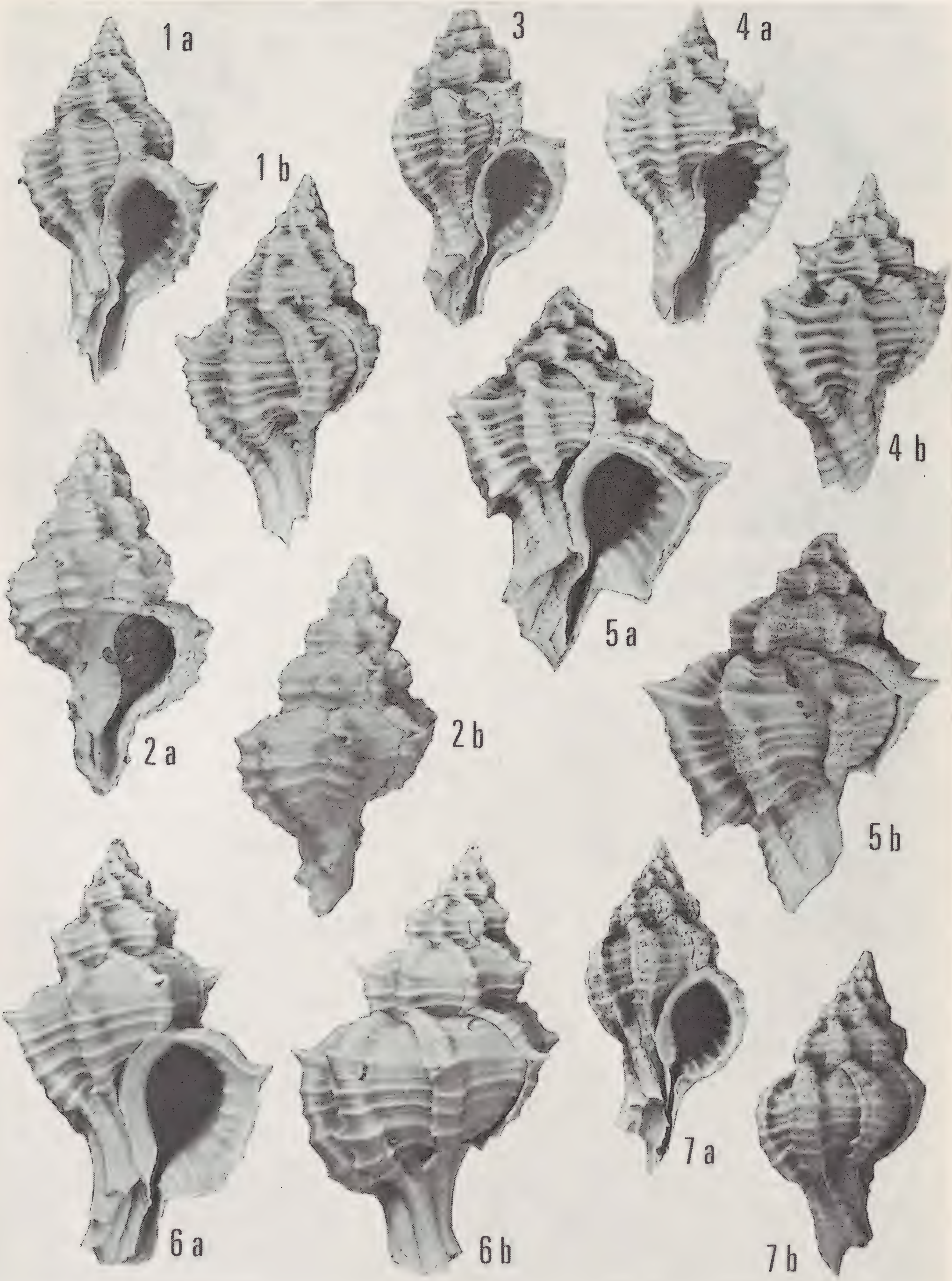



PLATE 7

*Occurrence*: Melajo Clay, Trinidad; upper Miocene.

*Discussion*: Assigned with a query to the genus *Calotrophon* by Jung, this species seems better placed in the *Panamurex* group, inasmuch as the principal distinction between *Panamurex* and *Calotrophon* is the presence of the denticles on the inner lip of *Panamurex*. Admittedly this is a somewhat arbitrary distinction, for in overall shell morphology the species is more akin to the *Calotrophon* group, especially in the concave slope of the shoulder. McLean and Emerson (in press) have just shown that *Calotrophon* is to be placed in the Muricinae and this species clearly demonstrates the relationship. However, it is not thought to be the direct ancestor to the *Calotrophon* line as there are members of that genus also present in the upper Miocene of Florida.

## Poirieria (Panamurex) carnicolor (Clench and Pérez Farfante)

Plate 6, figs. 6a, 6b

*Murex* (*Phyllonotus*) *interserratus* Sowerby. Dall, 1889, Harvard Mus. Comp. Zool., Bull., v. 18, p. 199 (*not* of Sowerby, 1879).
*Murex* (*Murexsul*) *carnicolor* Clench and Pérez Farfante, 1945, Johnsonia, v. 1, no. 17, p. 48, pl. 25, figs. 1-4.

*Diagnosis*: "Shell small, about 20 mm in length, highly spinose and rather thin. Whorls seven to eight, angulated at the shoulder, which gives rise to a turreted spire. The entire shell has a uniform flesh color. Spire extended. Suture irregular and not distinct, owing to small scale-like lamellae that overgrow it. Aperture ovate and colored similarly but paler than the outside. Parietal lip smooth, adhering above and slightly erect below. Palatal lip finely crenulated and with a few emarginate denticles. Siphonal canal rather short, narrow and slightly recurved upward at the distal end. Previous canals remain only as short overlapping scales. Axial sculpture consists of six to seven rounded varices. Each varix consists of a series of overlapping laminae, the first lamina giving rise to the first series of spines. Successive laminae are produced slightly forward of each other and following the general shape of the previous one formed. The spines are open, scale-like and rather short, except those developed at the shoulder of the whorls. These shoulder spines are rather low, sharply pointed and recurved upward. On the siphonal canal there is a large, spur-like spine corresponding to each varix. Additional axial sculpture consists of numerous low and irregular lamellae. Spiral sculpture consists of strong cords which connect the spines on one varix with the corresponding spines on the next. Nuclear whorls one and one-half, small, rounded, smooth and colored white. [Early] Post-nuclear whorls sculptured the same as all of the later whorls but having more varices. Periostracum absent. Operculum unknown." (Clench and Pérez Farfante, 1945).

Dimensions of holotype: height 20 mm, diameter (excluding spines) 10 mm.
Holotype: Harvard MCZ 7305.
Type locality: *Blake* Station 273, off Barbados, Lesser Antilles, in 103 fathoms.
*Occurrence:* Recent only.
*Figured specimen*: USNM 679266; height 28 mm, diameter 16 mm; locality, *Oregon* Station 5070, off Nevis, Leeward Islands, in 50-60 fathoms.

*Discussion*: The species which Dall (1889, p. 199) cited in the *Blake* Report as "*Murex interserratus* Sowerby" is not that species but a new one given the name *Murex carnicolor* by Clench and Pérez Farfante. At the same time Dall included in his synonymy the figure given by Sowerby (1879, fig. 208) for "*Murex*" *pazi* Crosse, but Sowerby's figure is indeed a good representation of that species and is not *P. carnicolor*.

The *Blake* took *P. carnicolor* in depths of 88 and 103 fathoms, and the U. S. Fish and Wildlife Service R/V *Oregon* has taken one specimen in 162 fathoms (Station 5913) and another, here figured, in 50 to 60 fathoms, which is the shallowest occurrence known. All records are from the Lesser Antilles and this seems to be the extent of the range of the species.

Although assigned to the subgenus *Murexsul* by Clench and Pérez Farfante, this species is more closely allied with the *Panamurex* group, possessing the characteristic denticulations on the inner lip. These denticulations are not developed on the holotype, nor is its outer lip complete. In the specimen figured here (plate 6, fig. 6) the shell is of an adult individual and better demonstrates the affiliations. *P. carnicolor* is exceedingly like the Miocene *P. lychnia* from the Chipola Formation of Florida, the only difference being that *P. carnicolor* is more spinose than the older species, with a more constricted anterior canal.

The species "*Murex*" *interserratus* Sowerby, with which *P. carnicolor* was confused by Dall, is indeed similar to it. However, it is not thought that the two are synonymous.

The holotype of "*M.*" *interserratus* has not been located but from Sowerby's original description there seem to be certain differences in the two species. Sowerby's shell was said to be of a pale grayish-white color, but the flesh-pink color of *P. carnicolor* is very characteristic. The aperture of Sowerby's species is almost circular and does not seem to fold into the shoulder spine in the manner of *P. carnicolor*. The circle of long spines on the siphonal canal of *P. carnicolor* are lacking in "*M.*" *interserratus*. Nevertheless, the two forms are much alike and "*M.*" *interserratus* is almost certainly to be referred to the subgenus *Panamurex*, although the denticulations on the inner lip are not visible in the illustration, nor does Sowerby mention them in his description. As the type locality for this species is not known, little more can be said about it at this time, except to note its affinities with *P. carnicolor*.

## Poirieria (Panamurex) velero
## E. H. Vokes, n. sp.

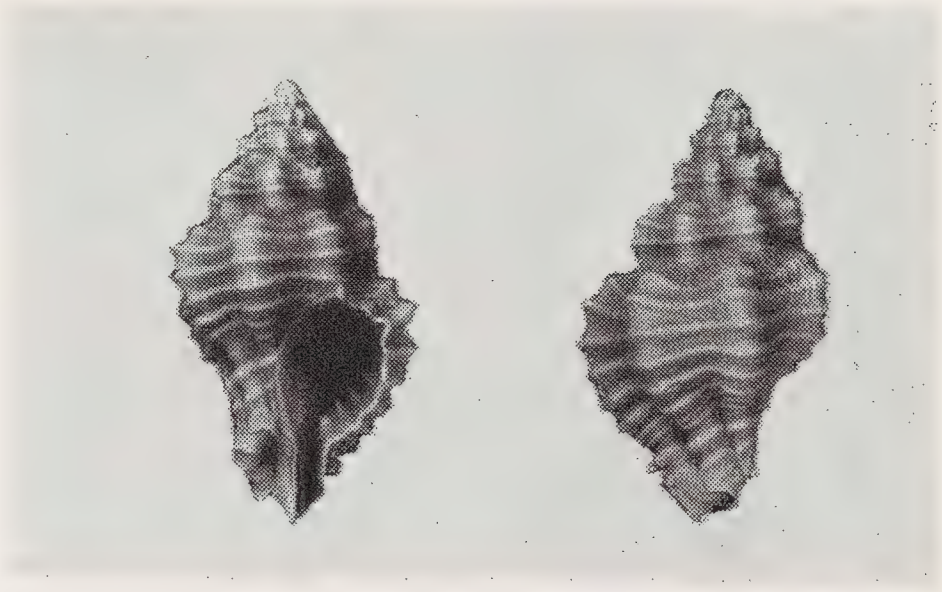
Text figure 1

*Diagnosis*: Nucleus of one and one-half smooth whorls, six post-nuclear whorls in the adult. Axial ornamentation beginning with 12 small nodes on first postnuclear whorl, diminishing to nine and then to seven on about the fourth and all subsequent whorls. Small open spinelets developed where spiral cord crosses these nodes at the shoulder, beginning on the second and persisting to about the fourth post-nuclear whorl, but disappearing on later whorls. Spiral ornamentation consisting of rounded spiral cords, riding up on the axial nodes to form strong ridges, somewhat weaker in the interspaces; two, then three on early whorls and nine to ten on body whorl. Entire shell surface covered with minute, scabrous, axial growth lines. Suture appressed, sigmoidal in form, rising up in the internodal areas and sinking down below the nodes of the previous whorl. Aperture oval, outer lip bearing about eight strong internal lirae, with four denticles at anterior end of columellar lip. Anterior canal open, slightly recurved, previous canals forming a small fasciole. Shell surface covered with a limy coating, when removed color is revealed to be a light reddish-brown, slightly darker on spiral ridges. Operculum muricoid.

Dimensions of holotype: height 14.2 mm, diameter 8 mm.

Holotype: LACM-AHF 1406.

Type locality: R/V *Velero* III Stations A 13-39 and A 14-39, one to two miles southwest of Cabo de Vela, Guajira Peninsula, Colombia (12°11′N, 72°11′W), in 10-22 fathoms, 8 April 1939, 12 specimens.



Text figure 1. *Poirieria* (*Panamurex*) *velero* E. H. Vokes, n. sp. LACM-AHF 1406 (holotype). (× 2) Height 14.2 mm, diameter 8 mm; locality, two miles southwest of Cabo de la Vela, Colombia, in 21-22 fathoms.

*Occurrence*: Recent only, northern South America.

*Figured specimen*: LACM-AHF 1406 (holotype).

*Discussion*: James H. McLean, of the Los Angeles County Museum of Natural History, and William K. Emerson, of the American Museum of Natural History, while engaged in research on the genus *Calotrophon*, discovered in the collections of the Allan Hancock Foundation, now on loan to the Los Angeles County Museum, several specimens of a new muricine species from the northern coast of South America. Recognizing the affinity with the *Panamurex* group, Dr. Emerson kindly passed these specimens on to the writer and she was astounded by the similarity to *P.* (*P.*) *mauryae* Vokes, n. sp. The two forms are very closely related with the most marked difference being in the greater strength of the spiral ribbing in the modern species. This unmistakable likeness gives weight to the ecologic inferences that may be drawn from *P. velero* with respect to the ecology of the Chipola Formation where *P. mauryae* is common. There are more than 20 specimens of *P. velero* known, from four different stations ranging from 2 to 24 fathoms in depth, with a sandy or coralline bottom type. This seems to agree well with the occurrence of *P. mauryae* in the calcarenite facies of the Chipola.

The material for *P. velero* was collected during the Allan Hancock Foundation Atlantic Expedition of 1939, at four Caribbean

stations, ranging from Cabo de la Vela, Colombia, through St. Nicolas Bay, Aruba, to Isla Cubagua, Venezuela. Although this new species occurs in the same general region as *P. (Panamurex) hutchisoni* (Jung), from the upper Miocene of Trinidad, it nevertheless seems more closely related to *P. mauryae* than to *P. hutchisoni*. This may well be a facies control problem as *P. hutchisoni* occurs in a clay but *P. mauryae* occurs in an environment similar to that of *P. velero*.

## V. Locality Data

The following are Tulane University fossil locality numbers:

60. Jackson Bluff Fm., borrow pits at Jackson Bluff, Ochlockonee River (NW ¼ Sec. 21, T1S, R4W), Leon Co., Florida.
66. Byram Marl, type locality, west bank of Pearl River, at Byram, Hinds Co., Mississippi.
69A. Shoal River Fm., first ravine upstream from Shell Bluff, Shoal River (NW ¼ Sec. 4, T3N R21W), about 3½ miles north of Mossyhead, Walton Co., Florida.
70. Chipola Fm., Ten Mile Creek, at bridge of Florida Highway 73 (NW ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.
72. Jackson Bluff Fm., Alum Bluff (upper beds), Apalachicola River (NE ¼ Sec. 24, T1N, R8W), Liberty Co., Florida.
73. Jackson Bluff Fm., "Dripping Springs," Four Mile Creek, about 1000 ft. upstream from bridge of Florida Highway 73 (NE ¼ Sec. 36, T1N, R10W), Calhoun Co., Florida.
91. Oak Grove Sand, type locality, west bank of Yellow River, about 100 yards below bridge at Oak Grove (NE ¼ Sec. 20, T5N, R23W), Okaloosa Co., Florida.
99. Moodys Branch Marl, Montgomery Landing (also known as Creola Bluff), west bank of Red River (Sec. 20, T8N, R5W), Grant Parish, Louisiana.
196. Chipola Fm., Ten Mile Creek, about ¼ mile upstream from bridge of Florida Highway 73 (NE ¼ Sec. 11, T1N, R10W), Calhoun Co., Florida.
325. Matthews Landing Marl, roadcut on Alabama Highway 10, 8.6 miles northeast of railroad station at Kimbrough, Wilcox Co., Alabama.
449. Ocala Limestone, quarry at Haile, on Florida Highway 235, about two miles north of Newberry, Alachua Co., Florida.
453. Chipola Fm., Alum Bluff (lower beds), Apalachicola River (NE ¼ Sec. 24, T1N, R8W), Liberty Co., Florida.
456. Chipola Fm., Ten Mile Creek, about ¼ mile downstream from bridge of Florida Highway 73 (NW ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.
457. Chipola Fm., west bank of Chipola River, about ½ mile below Ten Mile Creek (SW ¼ Sec. 17, T1N, R9W), Calhoun Co., Florida. (Same as USGS 2213, 2564, and 3419, "One mile below Bailey's ferry.")
458. Chipola Fm., east bank of Chipola River, above Farley Creek (SW ¼ Sec. 20, T1N, R9W), Calhoun Co., Florida.
546. Chipola Fm., Ten Mile Creek, about 1½ miles west of Chipola River (NW ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida. (? = USGS 2212, "one mile west of Bailey's Ferry.")
547. Chipola Fm., west bank of Chipola River, about 2000 ft. above Four Mile Creek (SW ¼ Sec. 29, T1N, R9W), Calhoun Co., Florida.
554. Chipola Fm., east bank of Chipola River at power line crossing (SW ¼ Sec. 17, T1N, R9W), Calhoun Co., Florida.
555. Chipola Fm., east bank of Chipola River, about 1000 ft. above Four Mile Creek (SW ¼ Sec. 29, T1N, R9W), Calhoun Co., Florida.
638. Agueguexquite Fm., roadcut and quarry on Mexico Highway 180, 14 miles east of junction with side road into Coatzacoalcos, Veracruz, Mexico.
655. Chipola Fm., Ten Mile Creek, about 0.1 mile downstream from bridge of Florida Highway 73 (NW ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.
705. Bowden Fm., type locality, Bowden, east of Port Morant, Parish of St. Thomas, Jamaica.
708. Chipola Fm., at small waterfall on tributary to Ten Mile Creek, south bank, about ¼ mile downstream from bridge of Florida Highway 73 (NW ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.
709. Chipola Fm., south bank of Ten Mile Creek, about ¼ mile downstream from bridge of Florida Highway 73 (NW ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.
710. Chipola Fm., Ten Mile Creek, just upstream from mouth of Mayo Mill Branch (NE ¼ Sec. 11, T1N, R10W), Calhoun Co., Florida.
735. Matthews Landing Marl, roadcut on Alabama Highway 10, 10 miles northeast of railroad station at Kimbrough, Wilcox Co., Alabama.
757. Gatun Fm., roadcut on south side of Boyd-Roosevelt Highway at junction of road to "Refinería Panamá, S.A.," just east of Cativa, Prov. of Colón, Panamá.
787. Chipola Fm., Ten Mile Creek, south bank about 1½ miles west of Chipola River (SE ¼ Sec. 12, T1N, R9W), Calhoun Co., Florida.
797. Pinecrest Beds, material exposed during construction of "Alligator Alley", 13.3 miles east of Florida Highway 29 (T49S, R32E), Collier Co., Florida.

810. Chipola Fm., east bank of Chipola River, opposite mouth of Taylor Branch (SW ¼ Sec. 17, T1N, R9W), Calhoun Co., Florida.
817. Chipola Fm., south side of Ten Mile Creek, large gully on the property of Mr. A. Sexton (1967) (SE ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.
818. Chipola Fm., Farley Creek, 0.1 mile west of bridge of Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.
820b. Chipola Fm., Farley Creek (lower beds), at bridge of Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.
821. Chipola Fm., Farley Creek, 0.1 mile east of bridge of Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.
825. Chipola Fm., Farley Creek at abandoned mill about ¼ mile west of bridge of Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.
827. Chipola Fm., Farley Creek, about ½ mile west of bridge of Florida Highway 275 (SE ¼ Sec. 20, T1N, R9W), Calhoun Co., Florida.
828. Chipola Fm., Farley Creek, just upstream from mouth of unnamed tributary about ¾ mile downstream from bridge of Florida Highway 275 (SE ¼ Sec. 20, T1N, R9W), Calhoun Co., Florida.
830. Chipola Fm., Ten Mile Creek, at power line crossing about one mile west of Chipola River (SE ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.
831. Chipola Fm., Ten Mile Creek [lowest Chipola beds exposed], slightly less than one mile west of Chipola River (SW ¼ Sec. 7, T1N, R9W), Calhoun Co., Florida.
866. "Silverdale Beds," marl pit on north side of Webb creek and east side of unnumbered county highway, Silverdale, Onslow Co., North Carolina.
950. Chipola Fm., Chipola River, west bank about 2000 ft. above Farley Creek (SW ¼ Sec. 20, T1N, R9W), Calhoun Co., Florida.
951. Chipola Fm., Ten Mile Creek, about 1¼ miles west of Chipola River (SE ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.
958. Gatun Fm., hillslope on east side of road from Boyd-Roosevelt Highway to "Refinería Panamá, S. A.," about ½ km north of junction, just east of Cativa, Prov. of Colón, Panamá.
959. Gatun Formation, roadcut on road to "Refinería Panamá S. A.," about 100 mts. south of refinery gate, Prov. of Colón, Panamá.
993. Weches Fm., roadcut and glade on north side Texas Highway 21, 3½ miles west of junction with Texas F. M. 95 at Chireno, Nacogdoches Co., Texas.
998. Chipola Fm., Ten Mile Creek, about 1¼ miles west of Chipola River (SE ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.
999. Chipola Fm., Farley Creek, about 1000 yds. downstream from bridge of Florida Highway 275 (SW ¼ Sec. 21, T1N, R9W), Calhoun Co., Florida.
1025. Concepción Fm., road cut on east side of road from Nuevo Teapa to Ixhuatlán, 0.5 mile south of junction with Mexico Highway 180, Veracruz, Mexico.

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# PALEONTOLOGICAL NOTES

## *HEXAPLEX (HEXAPLEX) ENGONATUS* (CONRAD): ERRATA AND CORRIGENDA

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In the previous part of this monograph the original reference for the species *Hexaplex (Hexaplex) engonatus* was incorrectly cited. It should have read:

> *Murex engonatus* CONRAD, 1833, Fossil Shells Tertiary Formations North Amer., v. 1, no. 3, p. 30.

At the same time the writer stated that although the type locality for this species was said to be Claiborne, Alabama, no specimens had ever been taken from the Gosport Sand. Dr. Henryk B. Stenzel, of Louisiana State University, subsequently pointed out (*in litt.*) that it was probable the type specimen came from the Lisbon Formation, at the base of the section at Claiborne Bluff. Such a logical explanation had not occurred to the writer and she is not a little chagrined at the oversight.

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## NOTES ON THE FAUNA OF THE CHIPOLA FORMATION—II

## *CHICOREUS (SIRATUS) JULIAGARDNERAE*, NEW NAME FOR *MUREX GARDNERAE* VOKES *NON* DALL, WITH OBSERVATIONS ON THE SPECIES

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In 1963 the writer proposed the name *Murex (Murex) gardnerae* for a species from the Chipola Formation, which had been identified by Gardner as *Murex chipolanus* Dall. Subsequently the writer (Vokes, 1965, p. 183) changed the generic assignment to *Chicoreus (Siratus)* on the basis of the deflected siphonal canal. Later, in a work on the members of the subgenus *Phyllonotus*, it was shown (Vokes, 1967, p. 141) that the species originally named by Dall (1915, p. 70) as *Alectrion gardnerae* was a synonym of *Murex trophoniformis*, a *Phyllonotus*. This change had the result of making *Chicoreus (Siratus) gardnerae* (Vokes) a secondary homonym of *Chicoreus (Phyllonotus) gardnerae* (Dall). Not all readers will hold with these generic arrangements but if the two species are considered as *Murex (Siratus)* and *Murex (Phyllonotus)* the same problem arises. Only by considering *Siratus* and *Phyllonotus* as distinct genera or by separating them as *Murex (Siratus)* and *Chicoreus (Phyllonotus)* can this difficulty be bypassed and neither of these solutions is acceptable to the writer. Therefore, *Chicoreus (Siratus) juliagardnerae* is here proposed as a new name for *Murex gardnerae* E. H. Vokes, 1963, not *Murex gardnerae* (Dall, 1915).

At the time of the original description of "*Murex*" *gardnerae* Vokes (1963, p. 99) it was stated that the specimen figured by Gardner (1947, pl. 52, fig. 1) was an exceptionally large one, measuring 49 mm in height. Although several hundred additional specimens have been collected by the writer since that time this observation still holds true. Of the almost 600 specimens now in the Tulane collections, from 14 localities, only 26 measure more than 40 mm in height, and of that number only four exceed the size of Gardner's 49 mm specimen. As noted originally, the species is far more common on Ten Mile Creek than it is on the Chipola River. Of the 600 specimens mentioned above, a total of 29 came from but three lo-

calities on the river, although collections have been made at 16 river stations. The species is most common at the old locality cited as "Ten Mile Creek, one mile west of Bailey's Ferry" (USGS 2212 = TU 546), where 105 specimens have been taken. The species is also common at three other localities nearby on Ten Mile Creek (TU 830, 951 & 998) where an additional 206 specimens have been taken. These four localities and two of the three river localities (with 24 of the 29 specimens) are all in the basal beds of the Chipola Formation. Here the lithology is a sticky ocherous clay, which is found to be blue in color only if a great amount of weathered surface material is removed.

*Chicoreus (Siratus) chipolanus* occurs with *C. juliagardnerae* in the basal beds along Ten Mile Creek (at TU 546, 830, 951, & 998) in the same profusion but no specimens have been taken anywhere on the river. *C. chipolanus*, however, was evidently more adaptable to changes in ecology for in the upper beds of the formation along Ten Mile Creek, where the sediment changes to a fine arenaceous silt, *C. chipolanus* continues to be abundant while *C. juliagardnerae* diminishes in number. At TU 655, for example, there are 47 specimens of *C. juliagardnerae* to 101 of *C. chipolanus*. Neither species has ever been taken in the calcaranite facies of Farley Creek, suggesting that the ecologic requirements of both were limited to a relatively muddy bottom with quiet water, similar to the requirements of the living members of the group.

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# RECENT BOOKS

ATLAS OF THE GREAT BARRIER REEF, by W. G. H. Maxwell. Published by Elsevier Publishing Company, Amsterdam, London and New York, 1969, vi + 258 pp., $32.50

In this volume, the evolution of the Great Barrier Reef is described in terms of geology, biology, hydrology and bathymetry. The numerous reef types present in various parts of this vast marine province are defined with explanation of the factors leading to their development, including consideration of types of sediment on the reefs and on the sea floor between the reef areas. This unique reef province with its prolific and extensive growth is an ideal laboratory for reef studies and this book is a welcome reference for all interested in this subject. It is well illustrated with excellent photographs, drawings and folded maps.

COAL AND COAL-BEARING STRATA, edited by Duncan Murchison and T. Stanley Westoll. Published by American Elsevier Publishing Company, Inc., New York, 1969, xii + 418 pp., $28.50

The fifteen papers in this book are based on contributions to the 13th Inter-University Geological Congress held at Newcastle upon Tyne in January, 1965. Coal is treated in relation to the sediments with which it is associated and sections of the volume are devoted to the biological environment of coal formation and to geochemistry and metamorphism. Though most of the emphasis is on Carboniferous coals, descriptions of post-Carboniferous occurrences are included. The volume is well illustrated and comprehensive author and subject indexes are included. The thirteen authors are all actively working in this field; eight are British, five are German.

TULANE STUDIES IN GEOLOGY AND PALEONTOLOGY

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# MOLLUSCA OF THE "GLADES" UNIT OF SOUTHERN FLORIDA: PART I INTRODUCTION AND OBSERVATIONS

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In southern Florida there is a shell deposit lying above the Caloosahatchee Marl of late Tertiary age and below the Pleistocene Fort Thompson Formation. This paleontologically distinctive unit was temporarily designated as "Unit A" by Olsson (*in* Olsson and Petit, 1964, Bulls. Amer. Paleontology, v. 47, no. 217, p. 513, 521), pending its formal naming by Druid Wilson of the U. S. Geological Survey. To date this name has not been published and until it is formally proposed we must refer to it by some sobriquet. Appropriately, most local workers have been terming it the "Glades" for some time, so this name will continue to serve. To date, the deposit has been identified from the following south Florida counties: Glades, Indian River, St. Lucie, Martin, Palm Beach, Broward, and Hendry.

This "Glades" unit, while retaining a few upper Miocene species and some splendid forms from the Caloosahatchee Marl, also has a number of species peculiar to itself. Students of Recent shells should find it of particular concern for many mollusks living today in the Gulf and Caribbean appear to have evolved from this fauna.

One locality for the "Glades" is of special interest as it appears to be devoid of any mixture with the marine fauna from the Fort Thompson Pleistocene above or the older Caloosahatchee Marl below. This is the Belle Glade Rock Pit (W ½, NE ¼ Sec. 7, T44S, R37E) about a mile south of the city of Belle Glade, Florida, and just south of Florida Highway 80, in Palm Beach County. This rock pit is an artificial lake over a third of a mile long, north to south, and approximately 400 feet wide, east to west. Draglines have dredged to a depth of 30 feet and deposited highly fossiliferous spoil banks to the east and west, recently mostly on the western side. Extensive collecting by many fossil enthusiasts has been done, but special credit should be given to Mr. Robert C. Hoerle and his wife, Shirley, of West Palm Beach, Florida, who have assembled an amazing collection from this area. Mrs. Hoerle's list of the marine mollusks from the Belle Glade Rock Pit follows this section of the paper.

The writer has screened over a ton and a half of material from the pit and a careful search has made available a number of smaller shells in excellent condition. In addition to screening, two other methods of collecting, used by the author for many years, have proved very productive. The first consists of a careful examination of the contents of larger shells. Often many smaller species may be found, even such delicate things as *Cavolina* and *Haminoea*, and the contents of certain "marker" shells are a frequent aid in correlating each fauna. The second method is to split open fossil corals, which often yield pairs of the boring species in fine condition. These two methods may add 20% to a faunal list, and are worthy of recommendation.

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The spoil banks at the Belle Glade Rock Pit seem to indicate extremely varied ecological conditions through geologic time. The rich black surface earth is several feet thick, with blasting necessary in some areas to expose the shell marl below. A fresh water facies later appears, exact position undetermined, but perhaps 3 feet in depth, for chunks of 20 inches have been observed on the spoil banks. Such marl has vast numbers of several species of *Planorbella*, *Viviparus georgianus* (Lea), fine large *Pomacea*, plus *Notogillia* and *Fontigens*. This fresh water layer is thought to be "Unit 9" of DuBar (1958, Fla. Geol. Survey Bull. 40, p. 75). A land fauna is also associated, perhaps thin but important. Specimens, scarce or rare, include *Succinea*, *Euglandina rosea* (Férussac), *Polygyra*, and fine large *Bulimulus dealbatus* (Say). Several of these large *Bulimulus* have been taken, the largest 1¼ inches long and in good condition. It appears to be a new Florida record, for today only smaller races live much further north, mostly inland from the Gulf coast. The presence of *Bulimulus* is of particular interest, for it seems to indicate land at least 10 feet above sea-level. Below this fresh water and land fauna, under more typical marine conditions, the "Glades" fauna appears, occupying more than ⅔ of the pit depth as dredged to date. It is of interest to note that a brackish-water fauna is also present with *Vermicularia recta* Olsson and Harbison appearing frequently on the spoil banks, perhaps "Units 4 and 3" of DuBar (1958, Fla. Geol. Survey Bull. 40, p. 75). The writer has observed at Cochran Rock Pit, near La Belle, in Hendry County, Florida, an exposed "test pit" with *Mitra heilprini*, typical of the Caloosahatchee Marl, appearing in position only inches below a fine large colony of *Vermicularia recta*. This would indicate that the dredgings at the Belle Glade Rock Pit have reached the extreme lower level of the "Glades" age.

Environmental conditions during the "Glades" period must have been similar to those existing today off the ocean side of the Florida Keys. The greater portion was likely soft mud or marl with 1 or 2 fathoms of seawater and large beds of *Thalassia* or "turtlegrass." Sand bars, indicated by vast numbers of *Oliva* in the deposit, must also have existed, for *Oliva* would only have lived in such a situation. Rocky or reef bottom would appear to have been restricted, for species which require such an ecological situation prove scarce or rare, but the discovery of a few large *Cyphoma intermedium* (Sowerby) surely indicates some reef bottom supporting living gorgonians, but likely in limited numbers. The finding of *Cyphoma* and *Cavolina*, as well as great numbers of *Macrocallista maculata* (Linné), suggests an open sea, not bay conditions.

As early as 1935, during construction of dikes adjacent to Lake Okeechobee, considerable fossil collecting was done by Dr. Maxwell Smith, Dr. Henry A. Pilsbry and family, the McGinty family, and numerous other friends. The levee only a short distance northwest of Belle Glade appeared to be of a different age so frequent visits were made. Publication in the "Nautilus" of several new species resulted, including *Fusinus watermani* (M. Smith), *Murexiella graceae* (McGinty), and *Latirus jucundus* McGinty, all taken from this Belle Glade levee. Other "Glades" fossils were taken at Clewiston, and on the south side of the Caloosahatchee River from spoil banks just west of the railroad bridge near Ortona Lock. Several new species from this last locality were described in the "Nautilus," including *Murex anniae* M. Smith, *Latirus maxwelli* Pilsbry, and *Vasum floridanum* McGinty, all now to be placed in the "Glades" unit.

In 1967 a huge dragline, locally known as "Uncle Luke," widened the Caloosahatchee River and made extensive new areas available for collecting. A splendid "Glades" fauna was revealed about 2 miles west of Ortona Lock, appearing on both sides of the river. Dredging to a depth of 23 feet did not penetrate into the Caloosahatchee Marl, but showed a far better representation of the species that would have lived in a rocky situation during the "Glades" period than was available at the Belle Glade Rock Pit. A short list of some of these species is included at the end of this paper. It is not thought that these deposits differ greatly in age, but far more likely slight variations result from differing ecological conditions. Near the surface at these Ortona Lock stations the first 6 feet is composed largely of Fort Thompson Pleistocene, evident by countless numbers of characteristic *Chione cancellata* (Linné),

such material usually being of a cream color. Below, the "Glades" deposit may often be distinguished by a more whitish coloration of the shell specimens.

Finding of land shell *Cerion incanum* (Binney) in this area is of considerable importance. This curious mollusk is known to live only within a few hundred yards of open sea upon land elevated above highest tide. The first fossil specimen was found one mile east of Ortona Lock by the writer's brother, Paul L. McGinty, in 1937. Recent collecting has provided two more specimens taken from an area 5.2 miles west of Ortona Lock, one from each side of the Caloosahatchee River. This would indicate adjacent land running parallel to the course of the present river for at least 6.2 miles, perhaps existing soon after the "Glades" age. *Cerion* has not been found from Belle Glade, nor has *Bulimulus* been taken near Ortona Lock.

The Ellobiid and rocky shore fauna is missing from these "Glades" stations, but would be of great interest if ever discovered. Ellobiids from one station in the Pinecrest Beds near Kissimmee proved quite sensational.

Key or marker fossils are extremely useful for estimating the age of any deposit, for often a mixed and confusing situation exists on the spoil banks where at least three different layers may be jumbled together. Excellent key fossils for the "Glades" are:

*Fusinus watermani* (M. Smith)
*Murex anniae* M. Smith
*Strombus mayacensis* Tucker & Wilson
*Anadara aequalitas* (Tucker & Wilson)
*Chicoreus dilectus* (Adams)
(All found only in the "Glades")

For the Caloosahatchee Marl deposits useful markers are:

*Conus adversarius tryoni* Heilprin.
(sinistral)
*Siphocypraea problematica* (Heilprin)
*Mitra heilprini* Cossmann
*Chicoreus floridanus* E. H. Vokes
(Not found in the "Glades")

*Jenneria loxahatchiensis* (Maxwell Smith, 1936) and *Morum* (*Cancellomorum*) *macgintyi* M. Smith, 1937, are thought to belong to the "Glades," but have not yet been found at the Belle Glade Rock Pit or the stations 2 miles west of Ortona Lock, so their exact stratigraphic position remains uncertain.

In conclusion the writer wishes to express gratitude to his brother, Paul L. McGinty, for our work has been a team effort and without his help might never have been done. Many others have assisted and special thanks are due to friends, property owners and construction contractors for facilitating this study.

An abbreviated list of species from the Belle Glade Rock Pit for comparison with the area two miles west of Ortona Lock follows:

SOME MOLLUSCAN SPECIES OF THE "GLADES"

| | Belle Glade | Ortona Lock |
|---|---|---|
| *Pelecypoda* | | |
| * *Anadara aequalitas* (Tucker & Wilson) | Belle Glade | Ortona Lock |
| † *Barbatia tenera* (C. B. Adams) | Belle Glade | Ortona Lock |
| *Trachycardium emmonsi* (Conrad) | Belle Glade | Ortona Lock |
| *Semele perlamellosa* Heilprin | Belle Glade | Ortona Lock |
| *Corbula scutata* Gardner | Belle Glade | Ortona Lock |
| *Gastropoda* | | |
| *Pyrazus scalatus* (Heilprin) | Belle Glade | Ortona Lock |
| † *Cypraea cervus* Linné | Belle Glade? | Ortona Lock |
| † *Cyphoma intermedium* (Sowerby) | Belle Glade | |
| * *Strombus mayacensis* Tucker & Wilson | Belle Glade | Ortona Lock |
| *Tonna galea* (Linné) | Belle Glade | |
| *Morum oniscus* (Linné) | Belle Glade | Ortona Lock |
| *Phalium inflatum* (Shaw) | Belle Glade | Ortona Lock |
| † * *Murex anniae* M . Smith | | Ortona Lock |
| *Murex bellegladeensis* E. Vokes | Belle Glade | |
| † *Murexiella glyptus* (M. Smith) | Belle Glade | Ortona Lock |
| † * *Murexiella graceae* (McGinty) | Belle Glade | |
| † *Tripterotyphis triangularis* (A. Adams) | | Ortona Lock |

| | | |
|---|---|---|
| † *Bailya intricata* (Dall) | Belle Glade | Ortona Lock |
| † * *Monostiolum thomasi* Olsson | Belle Glade | Ortona Lock |
| *Melongena bispinosa* (Philippi) | Belle Glade | Ortona Lock |
| *Fasciolaria okeechobensis* Tucker & Wilson | Belle Glade | Ortona Lock |
| † * *Latirus jucundus* McGinty | Belle Glade | Ortona Lock |
| † * *Latirus maxwelli* Pilsbry | | Ortona Lock |
| * *Fusinus watermani* (M. Smith) | Belle Glade | Ortona Lock |
| * *Vasum floridanum* McGinty | | Ortona Lock |
| *Trigonostoma rugosa* (Lamarck) | Belle Glade | Ortona Lock |

* Species peculiar to the "Glades" fauna.
† Species which lived in rocky situations.

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# MOLLUSCA OF THE "GLADES" UNIT OF SOUTHERN FLORIDA: PART II LIST OF MOLLUSCAN SPECIES FROM THE BELLE GLADE ROCK PIT, PALM BEACH COUNTY, FLORIDA

SHIRLEY E. HOERLE
*WEST PALM BEACH, FLORIDA*

This report is a listing of 434 species collected over a period of five years, January, 1964 to January 1969, from a borrow pit south of the town of Belle Glade, Palm Beach County, Florida. The material is believed to be lower Pleistocene in age. Of the 165 species of Pelecypoda, 8 species of Scaphopoda and 261 species of Gastropoda only about 15% are extinct. The remaining 85% are found living today in Florida and Caribbean waters. Those species marked with an asterisk are thought to be extinct.

After each species is an abbreviated reference to a published figure of the form. Complete references are given at the end of the paper. Frequency of the species is coded as follows:

R = Rare (1-5 specimens)

U = Uncommon (5-20 specimens)

C = Common (20-100 specimens)

A = Abundant (over 100 specimens)

## Class Pelecypoda

### Family Nuculidae

| | | |
|---|---|---|
| *Nucula proxima* Say | U | Smith, p.25, pl.2, fig.1 |

### Family Nuculanidae

| | | |
|---|---|---|
| *Nuculana acuta* (Conrad) | U | Smith, p.26, pl.2, fig.2 |

### Family Arcidae

| | | |
|---|---|---|
| *Arca imbricata* Bruguière | U | W & A, p.158, pl.30, fig.e |
| *Arca zebra* Swainson | C | W & A, p.157, pl.30, fig.l |
| *Barbatia tenera* (C. B. Adams) | C | W & A, p.158, pl.30, fig.g |
| *Barbatia tenera* (C. B. Adams) var. | U | |
| *Barbatia candida* (Helbling) | U | W & A, p.158, pl.30, fig.i |
| *Barbatia domingensis* (Lamarck) | R | W & A, p.158, pl.30, fig.d |

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| | | |
|---|---|---|
| *Arcopsis adamsi* (Dall) | U | W & A, p.159, pl.30, fig.f |
| **Anadara aequalitas* (Tucker & Wilson) | C | T & W, no.65, p.3, pl.2, fig.6 |
| *Anadara transversa* (Say) | A | RTA, p.345, pl.27, fig.s |
| *Anadara catasarca* (Dall) | C | TU, v.7, no.1, p.28, pl.6, fig.4 |
| *Anadara lienosa* (Say) | C | Gard., 199-A, p.23, pl.2, fig.7 |
| **Eontia playtyura* (Dall) | C | Dall, v.3, pt.4, p.632 |

Family Glycymeridae

| | | |
|---|---|---|
| *Glycymeris arata floridana* Olsson & Harbison | U | O & H, p.31, pl.1, figs.5,5a |
| *Glycymeris pectinata* (Gmelin) | R | W & A, p.161, pl.31, fig.a |

Family Mytilidae

| | | |
|---|---|---|
| *Crenella divaricata* (Orbigny) | U | W & A, p.161, text fig.26 |
| *Lithophaga* sp. undet. | U | |
| *Modiolus americanus* Leach | R | W & A, p.162, pl.31, fig.k |
| *Brachidontes exustus* (Linné) | C | W & A, p.162, pl.31, fig.f |
| *Musculus lateralis* (Say) | U | W & A, p.163, pl.31, fig.c |
| *Gregariella coralliophaga* (Gmelin) | R | W & A, p.164, pl.31, fig.l |
| *Botula fusca* (Gmelin) | R | W & A, p.163, pl.31, fig.d |

Family Pteriidae

| | | |
|---|---|---|
| *Pteria colymbus* (Röding) | U | RTA, p.359, pl.35, fig.d |
| *Pinctada radiata* (Leach) | U | W & A, p.166, pl.32, fig.b |

Family Pinnidae

| | | |
|---|---|---|
| *Pinna* sp. undet. (fragments) | C | |

Family Isognomonidae

| | | |
|---|---|---|
| *Isognomon ?radiatus* (Anton) | R | W & A, p.165, pl.32, fig.a |

Family Ostreidae

| | | |
|---|---|---|
| **Ostrea sculpturata* Conrad | U | O & H, p.50, pl.4, figs.1-1b |
| *Ostrea virginica* Gmelin | R | O & H, p.49, pl.5, figs.2,2a |
| *Ostrea* sp. undet. | U | |

Family Pectinidae

| | | |
|---|---|---|
| *Pecten raveneli* Dall | U | W & A, p.167, pl.32, fig.f |
| *Lyropecten nodosus* (Linné) | R | W & A, p.169, pl.4, fig.b |
| *Lyropecten antillarum* (Récluz) | R | W & A, p.169, pl.33, fig.f |
| *Aequipecten muscosus* (Wood) | C | W & A, p.170, pl.33, fig.e |
| *Aequipecten gibbus* (Linné) | C | W & A, p.170, pl.33, fig.i |
| *Aequipecten* sp. undet. # 1 | C | |
| *Aequipecten* sp. undet. # 2 | C | |

Family Limidae

| | | |
|---|---|---|
| *Lima lima* (Linné) | U | W & A, p.171, pl.34, fig.f |
| *Lima pellucida* C. B. Adams | R | W & A, p.171, pl.34, fig.e |
| *Lima scabra* (Born) | U | W & A, p.171, pl.34, fig.c |
| *Limatula subauriculata* (Montagu) | R | McL, p.36, pl.7, fig.7 |

Family Spondylidae

| | | |
|---|---|---|
| *Spondylus americanus* Hermann | U | RTA, p.369, pl.36, fig.b |
| *Plicatula gibbosa* Lamarck | U | RTA, p.361, pl.35, fig.e |

Family Anomiidae

| | | |
|---|---|---|
| *Anomia simplex* Orbigny | U | W & A, p.172, pl.34, fig.h |

Family Crassatellidae

| | | |
|---|---|---|
| *Eucrassatella speciosa* (A. Adams) | A | RTA, p.377, pl.30, fig.z |
| *Crassinella lunulata* (Conrad) | U | W & A, p.173, pl.35, fig.k |
| *Crassinella* sp. undet. | U | |

Family Carditidae

| | | |
|---|---|---|
| *Cardita floridana* (Conrad) | R | RTA, p.378, pl.30, fig.a |
| *Venericardia tridentata* (Say) | U | Smith, p.44, pl.14, figs.5a,5b |

### Family Lucinidae

| | | |
|---|---|---|
| *Lucina pensylvanica* (Linné) | C | Smith, p.46, pl.15, fig.1 |
| *Lucina multilineata* Tuomey & Holmes | C | RTA, p.386, text fig.78f |
| *Phacoides nassula* (Conrad) | C | Smith, p.46, pl.16, fig.8 |
| **Phacoides waccamawensis* (Dall) | C | Dall, v.3, pt.6, p.1386, pl.52, fig.2 |
| **Phacoides disciformis* (Heilprin) | U | O & H, p.84, pl.7, figs.1-1b |
| *Phacoides radians* (Conrad) | U | W & A, p.177, pl.36, fig.j |
| *Anodontia alba* Link | A | W & A, p.177, pl.36, fig.e |
| **Miltha carmenae* H. E. Vokes | U | TU, v.7, no.3, p.122, pl.7, figs.1-5 |
| *Codakia orbiculata* (Montagu) | U | W & A, p.178, pl.36, fig.h |
| *Codakia orbiculata imbricata* (C. B. Adams) | R | Cl. & T, p.292, pl.46, figs.7,8 |
| *Codakia orbicularis* (Linné) | R | McL, p.60, pl.12, fig.1 |
| *Codakia costata* (Orbigny) | R | McL, p.60, pl.12, fig.2 |
| *Divalinga quadrisculcata* (Orbigny) | U | W & A, p.179, pl.36, fig.l |
| *Divaricella dentata* (Wood) | R | McL, p.65, pl.13, fig.5 |

### Family Diplodontidae

| | | |
|---|---|---|
| *Diplodonta punctata* (Say) | R | W & A, p. 175, pl.35, figs.h,i |
| *Diplodonta semiaspera* Philippi | R | McL, p.67, pl.13, fig.6 |
| *Diplodonta nucleiformis* Wagner | R | W & A, p.175, pl.35, fig.j |
| *Thyasira trisinuata* (Orbigny) | R | W & A, p.176, pl.36, fig.f |

### Family Cyrenoididae

| | | |
|---|---|---|
| *Cyrenoida floridana* (Dall) | U | Naut., v.10, no.5, p.52 |

### Family Erycinidae

| | | |
|---|---|---|
| *Erycina* sp. undet. | R | |
| *Basterotia* sp. undet. | R | |
| **Bornia lioica* Dall | R | Dall, v.3, pt.4, p.920, pl.25, fig.6 |
| **Bornia mazyckii* Dall | R | Dall, v.3, pt.4, p.920, pl.25, fig.8 |
| **Ensitellops tabula* Olsson & Harbison | U | O & H, p.95, pl.8, figs.9,9a |
| **Fabella dalli* Olsson & Harbison | R | O & H, p.94, pl.9, fig.3 |

### Family Chamidae

| | | |
|---|---|---|
| *Chama macerophylla* Gmelin | C | W & A, p.179, pl.37, fig.b |
| *Chama congregata* Conrad | C | W & A, p.179, pl.37, fig.g |
| *Pseudochama radians* (Lamarck) | R | W & A, p.180, pl.37, fig.c |
| *Arcinella cornuta* (Conrad) | A | RTA, p.394, pl.37, fig.g |

### Family Cardiidae

| | | |
|---|---|---|
| **Trachycardium emmonsi* (Conrad) | C | O & H, p.100, pl.10, figs.1-1b |
| **Trachycardium declive* (Gabb) | R | Gabb, p.374, pl.47, fig.76 |
| *Trachycardium muricatum* (Linné) | U | W & A, p.182, pl.37, fig.m |
| *Dinocardium robustum* (Solander) | U | RTA, p.401, pl.32, fig.a |
| *Dinocardium robustum vanhyningi* Clench & L. C. Smith | R | RTA, p.401, pl.32, fig.b |
| *Americardia media* (Linné) | U | W & A, p.183, pl.38, fig.b |
| *Papyridea soleniformis* (Bruguière) | R | W & A, p.182, pl.37, fig.j |
| *Papyridea semisulcata* (Gray) | R | W & A, p.183, pl.37, fig.h |
| *Laevicardium laevigatum* (Linné) | U | W & A, p.184, pl.38, fig.e |

### Family Veneridae

| | | |
|---|---|---|
| *Antigona listeri* (Gray) | R | W & A, p.185, pl.38, fig.l |
| *Antigona rugatina* (Heilprin) | R | RTA, p. 405, pl.38, fig.m |
| *Chione intapurpurea* (Conrad) | U | RTA, p.407, pl.39, fig.g |
| *Chione cancellata* (Linné) | A | W & A, p.185, pl.38, fig.o |
| *Chione latilirata* (Conrad) | A | RTA, p.409, pl.39, fig.c |
| *Chione grus* (Holmes) | U | RTA, p.408, pl.32, fig.i |
| **Anomalocardia concinna* Olsson & Harbison | U | O & H, p.115, pl.13, fig.7 |
| *Anomalocardia brasiliana* (Gmelin) | U | W & A, p.187, pl.38, fig.g |
| *Pitar cordata* (Schwengel) | C | RTA, p.414, pl.38, fig.n |
| **Pitar sayana* (Conrad) | C | Dall, v.3, pt.6, p.1261, pl.54, fig.16 |
| *Pitar* (*Hyphantosoma*) sp. undet. | R | |
| *Gouldia cerina* (C. B. Adams) | U | W & A, p.189, pl.38, fig.k |
| *Macrocallista maculata* (Linné) | A | W & A, p.189, pl.39, fig.f |

| | | |
|---|---|---|
| *Mercenaria campechiensis* (Gmelin) | A | RTA, p.406, pl.32, fig.g |
| *Transennella cubaniana* (Orbigny) | U | McL, p.77, pl.15, fig.8 |
| *Transennella conradina* (Dall) | U | Dall "37," pl.90, fig.6 |
| *Dosinia elegans* (Conrad) | A | Smith, p.51, pl.19, fig.1, pl.18, fig.3 |
| *Cyclinella tenuis* (Récluz) | C | W & A, p.190, pl.39, fig.b |
| **Family Petricolidae** | | |
| *Rupellaria typica* (Jonas) | R | W & A, p.191, pl.44, fig.b |
| *Coralliophaga coralliophaga* (Gmelin) | R | McL, p.89, pl.18, fig.1 |
| **Family Mactridae** | | |
| *Mactra fragilis* Gmelin | U | W & A, p.204, pl.43, fig.g |
| *Mulinia* sp. undet. | C | |
| *Labiosa anatina* (Spengler) | R | W & A, p.204, pl.43, fig.j |
| *Rangia cuneata* (Gray) | A | RTA, p.450, text figs.91a,91b |
| **Family Tellinidae** | | |
| *Tellina mexicana* Petit | U | O & H, p.122, pl.14, fig.6 |
| *Tellina similis* Sowerby | R | O & H, p.127, pl.14, figs.8,8a |
| *Tellina* cf. *mera* Say | R | W & A, p.193, pl.40, fig.c |
| *Tellina sybaritica* Dall | U | W & A, p.193, pl.40, fig.e |
| *Tellina magna* Spengler | R | RTA, p.427, pl.40, fig.i |
| *Tellina alternata* Say | A | W & A, p.195, pl.40, fig.h |
| *Tellina lineata* Turton | R | RTA, p.427, pl.40, fig.h |
| *Tellina georgiana* Dall | C | W & A, p.195, pl.40, fig.a |
| *Tellina aequistriata* Say | U | W & A, p.196, pl.40, fig.f |
| *Tellina versicolor* (Cozzens) DeKay | U | P & Sch., p.79, pl.41, fig.298 |
| *Tellina* sp. undet. | R | |
| *Tellina gouldii* Hanley | U | John., v.4, no.45, p.270, pl.142, fig.4 |
| *Arcopagia fausta* Pulteney | R | W & A, p.197, pl.41, fig.l |
| *Strigilla* cf. *mirabilis* (Philippi) | R | O & McG, p.48,49, fig.5 |
| *Macoma brevifrons* (Say) | C | P & Sch., p.82, pl.16, fig.100A |
| *Macoma* cf. *pseudomera* Dall & Simpson | C | W & A, p.198, pl.41, fig.f |
| *Macoma tenta souleyetiana* (Récluz) | C | P & Sch., p.82, pl.44, fig.307 |
| *Macoma constricta* (Bruguière) | R | W & A, p.198, pl.41, fig.k |
| *Macoma tageliformis* Dall | R | W & A, p.198, pl.41, fig.i |
| *Macoma orientalis hendersoni* Rehder | U | W & A, p.199, pl.41, fig.b |
| *Apolymetis intastriata* (Say) | U | W & A, p.199, pl.41, fig.g |
| *Tellidora cristata* (Récluz) | C | RTA, p.430, pl.30, fig.o |
| **Family Sanguinolariidae** | | |
| *Tagelus divisus* (Spengler) | C | W & A, p.202, pl.42, fig.l |
| *Solecurtus cumingianus* (Dunker) | C | W & A, p.203, pl. 43, fig.h |
| *Solecurtus sanctaemarthae* (Orbigny) | R | W & A, p.204, pl.43, fig.f |
| **Family Semelidae** | | |
| *Semele proficua* (Pulteney) | C | W & A, p.200, pl.42, fig.e |
| *Semele purpurascens* (Gmelin) | C | W & A, p.200, pl.42, fig.c |
| **Semele perlamellosa* Heilprin | U | Heil., p.92, pl.11, fig.23 |
| *Semele bellastriata* (Conrad) | C | W & A, p.200, pl.42, fig.a |
| *Semele nuculoides* (Conrad) | U | W & A, p.200, pl.42, fig.b |
| *Cumingia tellinoides* (Conrad) | R | P & Sch., p.85, pl.17, fig.107 |
| *Abra aequalis* (Say) | C | P & Sch., p.85, pl.17, fig.106 |
| **Family Solenidae** | | |
| *Ensis minor* Dall (juvenile) | R | P & Sch., p.88, pl.17, fig.112 |
| **Family Myidae** | | |
| **Sphenia tumida* Lewis | R | TU, v.6, no.1, p.26, pl.1, figs. 1-4 |
| **Family Corbulidae** | | |
| **Corbula scutata* Gardner | R | Gard., 199-A, p.140, pl.23, figs.26, 30-32 |
| *Corbula caribaea* Orbigny | C | McL, p.115, pl.23, fig.8 |
| *Corbula swiftiana* C. B. Adams | R | Cl. & T, p.347, pl.48, figs.1,2 |
| *Corbula krebsiana* C. B. Adams | R | P & Sch., p.91, pl.18, fig.120 |
| *Corbula* sp. undet. | R | |
| **Notocorbula caloosae* (Dall) | C | O & H, p.148, pl.13, figs.10,10a |

| | | |
|---|---|---|
| **Family Gastrochaenidae** | | |
| *Gastrochaena hians* Gmelin | U | W & A, p.208, pl.44, fig.k |
| *Spengleria rostrata* (Spengler) | R | W & A, p.208, pl.44, fig.g |
| **Family Mesodesmatidae** | | |
| *Ervilia concentrica* Gould | R | McL, p.112, pl.23, fig.3 |
| **Family Hiatellidae** | | |
| *Hiatella arctica* (Linné) | R | P & Sch., p.92, pl.18, fig.122 |
| **Panopea floridana* Heilprin | R | Heil., p.91, pl.10, fig.21 |
| **Family Pholadidae** | | |
| *Diplothyra* sp. undet. | R | |
| **Family Pandoridae** | | |
| *Pandora bushiana* Dall | R | John., v.4, no.44, p.203-205, pl.123, figs.1-3 |
| *Pandora trilineata* Say | R | John., v.4, no.44, p.195-196, pl.121, figs.1-3 |
| **Pandora tuomeyi* Gardner & Aldrich | R | Gard., 199-A, pl.10, fig.27; pl.11, figs.9,10 |
| **Family Thraciidae** | | |
| *Cyathodonta semirugosa* Reeve | R | W & A, p.210, pl.44, fig.h |
| **Family Cuspidariidae** | | |
| *Cuspidaria granulata* (Dall) | R | Dall, 'Blake,' p.300, pl.3, fig.8 |
| *Cardiomya costellata* (Deshayes) | R | McL, p.49, pl.10, fig.3 |
| *Cardiomya gemma* Verrill & Bush | R | Smith, p.41, pl.13, fig.5 |
| *Cardiomya ornatissima* (Orbigny) | R | Smith, p.42, pl.65, fig.21 |
| **Family Verticordiidae** | | |
| *Verticordia ornata* (Orbigny) | R | W & A, p.210, pl.44, fig.i |
| **Class Scaphopoda** | | |
| **Family Dentaliidae** | | |
| *Dentalium eboreum* Conrad | U | Hend., p.66, pl.10, figs.3-5,8,9 |
| *Dentalium antillarum* Orbigny | U | Hend., p.44, pl.5, figs.1-4,6-8 |
| *Dentalium pilsbryi* Rehder | U | Hend., p.46,47, pl.6, figs.1-3 |
| *Dentalium sowerbyi* Guilding | U | Hend., p.79, pl.13, figs.2,3,10 |
| **Family Siphonodentaliidae** | | |
| *Cadulus carolinensis* Bush | R | Hend., p.102, pl.17, figs.6,7 |
| *Cadulus tetrodon* Pilsbry & Sharp | R | Hend., p. 101, pl.17, fig.5 |
| *Cadulus* sp. undet. | R | |
| *Cadulus quadridentatus* Dall | U | Hend., p.99, pl.17, figs.2,3 |
| **Class Gastropoda** | | |
| **Family Acmaeidae** | | |
| *Acmaea pustulata* Helbling | R | W & A, p.41, pl.6, fig.c |
| **Family Fissurellidae** | | |
| **Emarginula pilsbryi* Dall | R | O & H, p.360, pl.63, fig.8 |
| **Diodora carditella* (Dall) | U | O & H, p.358, pl.63, fig.3 |
| *Diodora cayenensis* (Lamarck) | C | John., v.1, no.11, p.5, figs.1-6 |
| *Lucapina sowerbii* (Sowerby) | R | John., v.1, no.10, p.14, pl.4, fig.1 |
| *Lucapina suffusa* (Reeve) | R | O & H, p.355, pl.63, fig.6a |
| *Lucapinella limatula* (Reeve) | U | W & A, p.38, pl.6, fig.d |
| **Lucapina textaranea* Olsson & Harbison | R | O & H, p.355, pl.63, figs.6,7 |

### Family Trochidae

| | | |
|---|---|---|
| *Calliostoma jujubinum* (Gmelin) | R | RTA, p.113, pl.3, fig.p |
| *Calliostoma euglyptum* (A. Adams) | R | RTA, p.112, pl.17, fig.w |
| *Calliostoma pulchrum* (C. B. Adams) | R | John., v. 4, no.40, p.17, pl.14 |
| *Calliostoma* cf. *yucatecanum* Dall | R | John., v.4, no.40, p.27, pl.19, figs. 1-4 |
| *Tegula fasciata* (Born) | U | Smith, p.78, pl.31, fig.4 |
| *Solariella* sp. undet. | R | |

### Family Turbinidae

| | | |
|---|---|---|
| *Turbo castaneus* Gmelin | U | RTA, p.123, pl.3, fig.g |
| *Turbo castaneus crenulatus* Gmelin | R | RTA, p.123 |
| *Arene tricarinata* (Stearns) | U | W & A, p.45, pl.7, fig.i |
| *Astraea phoebia* Röding | C | W & A, p.47, pl.8, fig.g |
| *Astraea americana* (Gmelin) (juvenile) | R | RTA, p.124, pl.3, fig.i |

### Family Phasianellidae

| | | |
|---|---|---|
| *Tricolia thalassicola* Robertson | U | W & A, p.48, pl.8, fig.d |

### Family Neritidae

| | | |
|---|---|---|
| *Smaragdia viridis merida* (Dall) | U | O & H, p.341, pl.60, figs.5-5b |

### Family Eulimidae

| | | |
|---|---|---|
| *Niso interrupta* (Sowerby) | R | P & Sch., p.117, pl.23, fig.153 |
| *Eulima bifasciata* Orbigny | R | W & A, p.83, pl.26, fig.i, text fig.13b |
| *Balcis intermedia* (Cantraine) | R | W & A, p.83, pl.26, fig.h, text fig.13c |
| *Balcis* sp. undet. | R | |
| *Athleenia burryi* Bartsch | R | Journal of the Washington Academy of Science, 1946, v.36, no.1, p.30, text fig.1 |

### Family Epitoniidae

| | | |
|---|---|---|
| *Epitonium rupicolum* (Kurtz) | R | RTA, p.165, pl.22, fig.e |
| *Epitonium rupicolum* (Kurtz) ?n.subsp. | R | |
| *Epitonium foliaceicostum* (Orbigny) | R | W & A, p.79, pl.14, fig.i |
| *Epitonium candeanum* (Orbigny) | R | W & A, p.81, pl.14, fig.b |
| *Epitonium novangliae* (Couthouy) | R | W & A, p.81, pl.14, fig.e |
| *Epitonium echinaticostum* (Orbigny) | R | W & A, p.79, pl.14, fig.g |
| **Epitonium junceum* Gardner | R | O & H, p.337, pl.58, fig.7 |
| **Opalia debouryi* (Dall) | R | Dall, v.3, pt.1, p.158, pl.20, fig.13 |
| *Depressiscala nautlae* (Mörch) | R | John., v.2, no.31, p.329, pl.159 |
| *Cirsotrema dalli* Rehder | R | RTA, p.161, pl.22, fig.c, text fig.40a |

### Family Vitrinellidae

| | | |
|---|---|---|
| *Episcynia multicarinata* (Dall) | R | Naut., v.59, no.3, p.81, pl.8, figs.6,6a |
| *Cyclostremiscus beaui bicarinatus* Guppy | R | O & H, (Pilsbry), p.427, pl.55, figs.1-1e |
| *Cyclostremiscus*(?) *trilix* (Bush) | R | O & H, (Pilsbry), p.429, pl.55, figs.2-2b |
| *Cyclostremiscus* sp. undet. | R | |
| **Solariorbis basilissus* Pilsbry | R | O & H, (Pilsbry), p.420, pl.56, figs.4-4c |
| *Solariorbis euzonus* Pilsbry & McGinty | R | O & H, (Pilsbry), p.420, pl.56, figs.2-2b |
| **Solariorbis funiculus* (Dall) | R | O & H, (Pilsbry), p.419, pl.53, figs.5-5e |
| *Teinostoma parvicallum* Pilsbry & McGinty | R | Naut., v.59, no.1, p.4, pl.2, fig.2 |
| *Teinostoma carinicallus* Pilsbry & McGinty | R | O & H, (Pilsbry), p.412, pl.49, figs.1-1e |
| *Teinostoma goniogyrus* Pilsbry & McGinty | R | Naut., v.59, no.1, p.3, pl.1, fig.8 |
| *Teinostoma* sp. undet. #1 | R | |
| *Teinostoma* sp. undet. #2 | R | |
| *Vitrinella blakei* Rehder | R | Naut., v.57, no.3, p.97, pl.9, figs.1,2 |
| *Aorotrema pontogenes* Schwengel & McGinty | R | Naut., v.56, no.1, p.17, pl.3, fig.3 |
| *Anticlimax tholus* (Pilsbry & McGinty) | R | Naut., v.59, no.3, p.79, pl.8, figs.1-1b |
| **Cochliolepis* cf. *holmesi* (Dall) | R | O & H, (Pilsbry), p.433, pl.52, figs.5-5b |
| *Cochliolepis striata* Dall | R | O & H, (Pilsbry), p.432, pl.52, fig.2 |
| **Parviturboides avitus* Pilsbry | R | O & H, (Pilsbry), p.436, pl.56, figs.3,3a |
| *Didianema pauli* Pilsbry & McGinty | R | Naut., v.59, no.1, p.12, pl.2, fig.10 |

### Family Rissoidae

| | | |
|---|---|---|
| *Rissoina chesneli* Michaud | U | Smith, p.97, pl.37, fig.18 |
| *Rissoina cancellata* Philippi | R | W & A, p.57, pl.10, fig.l |
| *Zebina browniana* (Orbigny) | U | W & A, p.58, pl.10, fig.f |
| *Rissoina decussata* (Montagu) | R | W & A, p.57, pl.10, fig.o |
| *Microdochus floridanus* Rehder | R | W & A, p.58, pl.10, fig.g |
| *Rissoa toroensis* Olsson & McGinty | R | O & McG, p.26, pl.4, fig.5 |
| *Alvania auberiana* (Orbigny) | R | W & A, p.58, pl.10, fig.k |

### Family Turritellidae

| | | |
|---|---|---|
| **Turritella subannulata* Heilprin | C | O & H, p.312, pl.44, fig.8 |
| **Turritella* aff. *apicalis* Heilprin | C | O & H, p.314, pl.44, figs.5,5a |
| *Lemintina decussata* (Gmelin) | R | O & H, p.305, pl.46, figs.3-3c |
| **Vermicularia recta* Olsson & Harbison | C | O & H, p.307, pl.46, figs.4-4c |
| *Vermicularia weberi* Olsson & Harbison | C | O & H, p.308, pl.47, figs.1-1b |

### Family Architectonicidae

| | | |
|---|---|---|
| *Architectonica nobilis* Röding | R | W & A, p.65, pl.11, fig.g |
| *Heliacus bisulcatus* (Orbigny) | R | W & A, p.65, pl.11, fig.f |

### Family Caecidae

| | | |
|---|---|---|
| *Caecum floridanum* Stimpson | R | O & H, p.317, pl.45, figs.1-1c |
| *Caecum regulare* Carpenter | U | O & H, p.317, pl.45, figs.2-2c |
| *Caecum imbricatum* Carpenter | U | O & H, p.318, pl.45, figs. 4-4b |
| *Caecum pulchellum* Stimpson | R | W & A, p.67, text fig.15a |
| *Meioceras nitidum* (Stimpson) | R | W & A, p.70, text fig.15c |

### Family Modulidae

| | | |
|---|---|---|
| *Modulus carchedonius* (Lamarck) | U | W & A, p.71, pl.11, fig.k |
| *Modulus modulus* (Linné) | U | W & A, p.70, pl.11, fig.j |

### Family Cerithiidae

| | | |
|---|---|---|
| *Cerithium floridanum* Mörch | C | O & H, p.282, pl.42, fig.1 |
| *Cerithium algicola* C. B. Adams | U | W & A, p.73, pl.13, fig.p |
| *Cerithium muscarum* Say | U | RTA, p.154, pl.19, fig.m |
| *Bittium varium* (Pfeiffer) | U | W & A, p.73, pl.13, fig.h |
| *Alabina adamsi* (Dall) | C | O & H, p.293, pl.48, fig.7 |
| *Alabina cerithidioides* (Dall) | R | O & H, p.292, pl.48, fig.9 |
| *Alaba incerta* (Orbigny) | R | W & A, p.74, pl.13, fig.r |
| *Seila adamsi* (H. C. Lea) | R | W & A, p.75, pl.13, fig.m |
| *Cerithiopsis greeni* (C. B. Adams) | R | Cl. & T, p.289, pl.37, figs.17,18 |
| *Cerithiopsis emersoni* (C. B. Adams) | R | W & A, p.74, pl.13, fig.c |
| *Triphora nigrocincta* (C. B. Adams) | R | W & A, p.76, pl.13, fig.k |

### Family Potamididae

| | | |
|---|---|---|
| **Pyrazus scalatus* (Heilprin) | C | O & H, p.291, pl.47, fig.12 |
| *Cerithidea costata* (da Costa) | R | RTA, p.152, pl.19, fig.u |

### Family Fossaridae

| | | |
|---|---|---|
| *Iselica anomala* (C. B. Adams) | R | W & A, p.85, pl.15, fig.e |

### Family Calyptraeidae

| | | |
|---|---|---|
| *Cheila equestris* (Linné) | R | W & A, p.84, pl.15, fig.m |
| *Crepidula aculeata* (Gmelin) | U | W & A, p.86, pl.15, fig.i |
| *Crepidula plana* Say | C | W & A, p.87, pl.15, fig.j |
| *Crepidula fornicata* (Linné) | U | RTA, p.170, pl.21, fig.m |
| *Crucibulum auricula* (Gmelin) | U | RTA, p.169, pl.21, fig.s |
| **Crucibulum* cf. *multilineatum* (Conrad) | C | Gard., 142-H, p.569, pl.56, figs.6,7 |

### Family Xenophoridae

| | | |
|---|---|---|
| *Xenophora conchyliophora* (Born) | U | W & A, p.88, pl.12, fig.b |

### Family Naticidae

| | | |
|---|---|---|
| *Natica canrena* (Linné) | U | W & A, p.96, pl.17, fig.g |
| *Natica pusilla* Say | U | RTA, p.191, pl.22, fig.j |
| *Sigatica semisulcata* (Gray) | R | O & H, p.271, pl.57, figs.5,5a |

| | | |
|---|---|---|
| *Polinices duplicatus* (Say) | U | RTA, p.186, pl.5, fig.k |
| **Polinices caroliniana* (Conrad) | U | O & H, p.268, pl.57, fig.6 |
| *Sinum perspectivum* (Say) | R | W & A, p.95, pl.17, fig.k |
| *Sinum maculatum* (Say) | R | W & A, p.95, pl.17, fig.h |
| *Sinum* sp. undet. | R | |

Family Lamellariidae

| | | |
|---|---|---|
| *Lamellaria* sp. undet. (fragment) | R | |

Family Cypraeidae

| | | |
|---|---|---|
| *Cypraea ?cervus* Linné (fragments) | R | RTA, p.180, pl.6, fig.f |

Family Eratoidae

| | | |
|---|---|---|
| *Erato maugeriae* Gray | R | W & A, p.90, pl.23, fig.c |
| *Trivia antillarum* Schilder | R | W & A, p.90, pl.16, fig.e |
| *Trivia pediculus* (Linné) | U | W & A, p.90, pl.16, fig.f |
| *Trivia quadripunctata* Gray | R | W & A, p.90, pl.16, fig.d |

Family Ovulidae

| | | |
|---|---|---|
| *Cyphoma intermedium* (Sowerby) | R | W & A, p.93, pl.16, fig.j |

Family Strombidae

| | | |
|---|---|---|
| **Strombus mayacensis* Tucker & Wilson | U | T & W, no.66, p.8, pl.1, fig.7; pl.3, figs.3,5 |
| *Strombus pugilis alatus* Gmelin | A | O & H, p.273, pl.34, fig.7 |

Family Tonnidae

| | | |
|---|---|---|
| *Tonna galea* (Linné) | U | John., v.2, no.26, p.173, pl.78 |

Family Cassididae

| | | |
|---|---|---|
| *Cassis madagascariensis spinella* Clench | R | John., v.1, no.16, p.15,16, pl.8 |
| *Morum oniscus* (Linné) | R | W & A, p.97, pl.23, fig.r |
| *Phalium inflatum* (Shaw)[1] | C | RTA, p.192, pl.9, fig.e |
| *Phalium peristephes* (Pilsbry & McGinty) | R | Naut., v.52, p.76, pl.5, fig.5 |

Family Ficidae

| | | |
|---|---|---|
| *Ficus papyratia* (Say) | C | O & H, p.258, pl.41, figs.1-1b |

Family Cymatiidae

| | | |
|---|---|---|
| *Cymatium poulseni* (Mörch) | R | W & A, p.100, pl.18, fig.e |

Family Muricidae

| | | |
|---|---|---|
| *Murex rubidum* Baker | U | TU, v.1, no.3, p.108, pl.4, figs.3,4 |
| *Murex bellegladeensis*[2] E. H. Vokes | U | TU, v.1, no.3, p.111, pl.4, figs.1a,1b |
| **Murexiella graceae* (McGinty) | R | Naut., v.53, no.3, p.84, pl.10, figs.2,2a |
| *Murexiella glypta* (M. Smith) | R | Naut., v.51, no.3, p.89, pl.6, fig.10 |
| *Chicoreus dilectus* (A. Adams) | C | TU, v.3, no.4, p.191, pl.3, fig.4 |
| *Chicoreus pomum* (Gmelin) | C | TU, v.5, no.3, p.149, pl.4, figs.4,5; pl.5, figs.4,5 |
| *Favartia cellulosa* (Conrad) | U | O & H, p.245, pl.36, fig.6,6a |
| *Muricopsis oxytatus* (M. Smith) | R | Naut., v.51, no.3, p.89, pl.6, fig.6 |
| *Pseudosalpinx ostrearum* (Conrad) | C | RTA, p.211, text fig.47g |
| *Attiliosa philippiana* (Dall) | R | Vel., (Emerson), v.10, no.4, p.379, pl.53, figs.1-5 |

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[1] Although placed in synonymy with *P. granulatum* by several authors, these two species are nevertheless distinct and have a completely different geographic and ecologic range in the Recent. This distribution will be the subject of a forthcoming paper by E. W. Andrews (E. H. Vokes).

[2] When this was originally named as a subspecies of *M. anniae* Smith there were no more than three specimens of *M. anniae* known to science, and the limit of variation was uncertain. Since that time new dredgings on the "Caloosahatchee Canal" west of Ortona Lock exposed thousands of specimens of true *M. anniae* and it is now evident that *M. bellegladeensis* is a valid species. *M. bellegladeensis* also occurs in the Recent fauna of the Gulf of Mexico from off Savannah, Georgia, to Galveston, Texas, in water of about 25 to 40 fathoms depth. (E. H. Vokes)

| | | |
|---|---|---|
| *Urosalpinx tampaensis* (Conrad) | C | Smith, p.116, pl.45, fig.5 |
| *Urosalpinx perrugata* (Conrad) | C | RTA, p.212, text fig.47d |
| *Eupleura caudata sulcidentata* Dall | C | P & Sch., p.154, pl.31, fig.215 |
| *Aspella senex* Dall | R | O & H, p.250, pl.39, fig.8 |
| **Aspella* (*Dermomurex*) cf. *jani* (Doderlein *in* Bellardi) | R | Montanaro, 1935, Paleont. Italica, v.35, p.47, pl.3, fig.20 |
| *Thais haemastoma floridana* (Conrad) | R | John., v.1, no.23, p.76, figs.1-4 |

Family Columbellidae

| | | |
|---|---|---|
| *Columbella rusticoides* Heilprin | R | O & H, p.229 |
| *Columbella* sp. undet. | R | |
| **Columbella* (*Eurypyrene*) sp. undet. #1 | U | |
| **Columbella* (*Eurypyrene*) sp. undet. #2 | R | |
| **Anachis gardnerae* Olsson & Harbison | U | O & H, p.236, pl.38, figs.6,6a |
| *Anachis albella* (C. B. Adams) | U | Cl. & T, p.251, pl.29, fig.2 |
| **Anachis caloosaensis* (Dall) | R | O & H, p.233, pl.38, figs.1-1b |
| *Anachis obesa* (C. B. Adams) | R | O & H, p.232, pl.38, fig.11 |
| *Nitidella argus* (Orbigny) | R | W & A, p.112, pl.20, fig.k |
| *Mitrella lunata* (Say) | R | RTA, p.223, pl.25, fig.gg |
| *Nassarina dalli* Olsson & Harbison | R | O & H, p.239, pl.39, fig.3 |

Family Buccinidae

| | | |
|---|---|---|
| *Bailya intricata* (Dall) | R | W & A, p.115, pl.21, fig.b |
| *Cantharus multangulus* (Philippi) | C | RTA, p.211, text fig.47f |
| *Cantharus tinctus* (Conrad) | C | W & A, p.117, pl.21, fig.k |
| *Engina turbinella* (Kiener) | U | RTA, p.232, pl.25, fig.w |
| *Colubraria lanceolata* (Menke) | U | W & A, p.116, pl.21, fig.m |
| **Monostiolum thomasi* Olsson | R | Olss., p.35, pl.9, figs.3,3a |

Family Busyconidae

| | | |
|---|---|---|
| *Busycon aspinosum* Hollister | U | Holl., p.90, pl.13, figs.3-5 |
| *Busycon sinistrum* Hollister | C | Holl., p.85, pl.11, figs.1-4,10,12 |
| *Busycon* sp. undet. (dextral) | U | |
| *Busycotypus spiratus pyruloides* (Say) | R | Holl., p.100, pl.15, figs.10,11 |
| *Melongena corona subcoronata* Heilprin | U | Smith, p.125, pl.28, fig.4 |
| *Melongena bispinosa* (Philippi) | C | Naut., v.48, no.4, p.120, pl.12, fig.8 |

Family Nassariidae

| | | |
|---|---|---|
| *Nassarius vibex* (Say) | R | O & H, p.220, pl.33, figs.1,1a |
| **Nassarius bidentatus* (Emmons) | U | O & H, p.222, pl.33, figs.4,4a |
| *Nassarius albus* (Say) | U | W & A, p.118, pl.21, fig.o |
| *Nassarius consensus* (Ravenel) | U | Smith, p.121, pl.46, fig.11 |

Family Fasciolariidae

| | | |
|---|---|---|
| *Fasciolaria gigantea* Kiener | C | Smith, p.126, pl.39, fig.3 |
| **Fasciolaria apicina* Dall | C | O & H, p.215, pl.35, fig.5 |
| **Fasciolaria okeechobensis* Tucker & Wilson | C | T & W, no.65, p.10, pl.1, fig.6 |
| **Latirus jucundus* McGinty | R | Naut., v.53, no.3, p.83, pl.10, fig.3 |
| *Latirus mcgintyi* Pilsbry | R | Naut., v.52, no.3, p.84, pl.5 |

Family Fusinidae

| | | |
|---|---|---|
| **Fusinus watermani* (M. Smith) | U | Naut., v.50, no.1, p.22, pl.9, fig.16 |
| *Fusinus timessus* (Dall) (??) | R | Dall, v.3, pt.1, p.127, pl.7, fig.6 |

Family Olividae

| | | |
|---|---|---|
| *Oliva sayana* Ravenel | A | O & H, p.183, pl.29, fig.1 |
| **Oliva edwardsi* Olsson | A | Olss., p.30, pl.6, fig.7 |
| *Olivella floralia* (Duclos) | U | P & Sch., p.176, pl.36, fig.249 |
| *Olivella pusilla* (Marrat) | U | Olss. Oliv., p.186, pl.8, fig.5 |
| *Olivella mutica* (Say) | U | Olss. Oliv., p.184, pl.9, figs.7-7b |
| **Jaspidella jacksonensis* (Mansfield) | U | Olss. Oliv., p.214, pl.16, fig.5 |

Family Turbinellidae

| | | |
|---|---|---|
| *Turbinella angulata* (Solander *in* Lightfoot) | R | TU, v.2, no.2, p.62, pl.3, fig.1; v.4, no.2, pl.2, fig.3 |
| **Turbinella hoerlei* E. H. Vokes | C | TU, v.4, no.2, p.68, pl.2, fig.1; pl.3, fig.1 |

### Family Mitridae

| | | |
|---|---|---|
| *Mitra* cf. *floridana* Dall | R | Smith, p.128, pl.50, fig.5 |
| *Vexillum* (*Uromitra*) sp. undet. | R | |
| *Pusia histrio* (Reeve) | R | W & A, p.126, pl.22, fig.i |
| *Pusia* cf. *albocincta* (C. B. Adams) | R | W & A, p.125, pl.22, fig.c |

### Family Volutidae

| | | |
|---|---|---|
| **Scaphella floridana* (Heilprin) | R | O & H, p.196, pl.27, figs.4-4b |

### Family Marginellidae

| | | |
|---|---|---|
| *Marginella aureocincta* Stearns | R | RTA, p.254, text fig.56b |
| *Marginella denticulata* Conrad | U | W & A, p.127, pl.23, fig.a |
| *Marginella haematita* Kiener | R | W & A, p.127, pl.23, fig.b |
| **Marginella* aff. *mansfieldi* Tucker & Wilson | R | T & W, no.66, p.11, pl.2, fig.6 |
| *Marginella amabilis* Redfield | R | O & H, p.207 |
| *Marginella succinea* Conrad | R | P & Sch., p.173, pl.36, fig.245 |
| **Marginella caloosana* Olsson & Harbison | R | O & H, p.202, pl.30, fig.10 |
| **Marginella belloides* Olsson & Harbison | R | O & H, p.203, pl.30, figs.6-6b |
| *Prunum apicinum* (Menke) | C | RTA, p.257, pl.11, fig.n; text fig.56g |
| *Prunum virginianum* Conrad | C | RTA, p.257, text fig.56h |
| *Hyalina tenuilabra* (Tomlin) | R | W & A, p.129, pl.23, fig.f |
| *Hyalina avena* Kiener | U | W & A, p.129, pl.23, fig.h |
| *Persicula lavalleeana* (Orbigny) | R | W & A, p.128, pl.23, fig.d |
| *Cypraeolina lacrimula* (Gould) | R | P & Sch., p.174, pl.36, fig.246 |

### Family Cancellariidae

| | | |
|---|---|---|
| *Cancellaria reticulata* Linné | C | W & A, p.126, pl.22, fig.h |
| *Trigonostoma tenera* (Philippi) | R | RTA, p.253, text fig.55d |
| *Trigonostoma rugosa* (Lamarck) | R | W & A, p.126, pl.22, fig.g |
| *Trigonostoma smithii* (Dall) | R | Dall, 'Blake,' p.129, pl.37, fig.1 |

### Family Turridae

| | | |
|---|---|---|
| **Daphnella cingulata* Dall | R | Dall, v.3, pt.1, p.38, pl.2, fig.3 |
| *Mangelia bartletti* (Dall) | U | W & A, p.137, pl.25, fig.f |
| *Crassispira ostrearum* (Stearns) | C | O & H, p.368, pl.16, figs.2,3 |
| **Crassispira acucincta* (Dall) | C | Dall, v.3, pt.1, p.32, pl.2, fig.11 |
| *Cerodrillia thea* (Dall) | R | RTA, p.270, text fig.57f |
| *Cerodrillia* cf. *schroederi* Bartsch & Rehder | R | P & Sch., p.182, pl.38, fig.262 |
| **Ithycythara maera rata* Fargo | R | O & H, (Fargo), p.382, pl.20, figs.2,2a |
| *Ithycythara lanceolata* (C. B. Adams) | R | W & A, p.137, pl.26, fig.r |
| *Ithycythara* sp. undet. | R | |
| *Pyrgocythara coxi* Fargo | R | O & H, (Fargo), p.384, pl.20, figs.3,3a |
| *Brachycythara biconica* (C. B. Adams) | R | RTA Cay. Ids., p.98, pl.3, fig.p |
| *Nannodiella melantica* (Dall) | R | W & A, p.136, pl.25, fig.r |
| **Nannodiella pauca* Fargo | R | O & H, (Fargo), p.408, pl.21, fig.8 |
| *Kurtziella limonitella* (Dall) | U | RTA, p.272, text fig.57a |
| *Kurtziella* sp. undet. #1 | R | |
| *Kurtziella* sp. undet. #2 | R | |
| **Vitricythara metria* (Dall) | R | O & H, p.396, pl.21, figs.1,1a |
| *Glyphoturris rugirima* (Dall) | R | P & Sch., p.189, pl.39, fig.273 |
| **Glyphostoma scoptes* Dall | R | Dall, v.3, pt.6, pl.60, fig.15 |
| *Glyphostoma* sp. undet. | R | |
| *Sedilia* sp. undet. | U | |
| *Monilispira leucocyma* (Dall) | U | RTA, p.271, text fig.57d |
| *Fenimorea moseri* (Dall) | C | Dall, 'Blake,' p.97, pl.36, fig.3 |

### Family Conidae

| | | |
|---|---|---|
| *Conus spurius atlanticus* Clench | C | RTA, p.260, pl.14, fig.p |
| *Conus verrucosus* Hwass | C | W & A, p.130, pl.24, fig.e |
| *Conus floridanus* Gabb | A | RTA, p.261, pl.14, fig.d |
| *Conus jaspideus* Gmelin | C | RTA, p.263, pl.14, fig.n |
| *Conus sozoni* Bartsch | R | RTA, p.261, pl.14, fig.c |
| *Conus daucus* Hwass | R | W & A, p.131, pl.24, fig.l |

| | | |
|---|---|---|
| **Family Terebridae** | | |
| *Terebra dislocata* (Say) | C | W & A, p.132, pl.25, fig.d |
| *Terebra protexta* (Conrad) | C | W & A, p.133, pl.25, fig.c |
| *Terebra concava* (Say) | U | O & H, p.168, pl.58, figs.9,9a |
| *Terebra arcas* Abbott | R | Naut., v.68, no.2, p.40, pl.2, fig.4 |
| **Family Bullidae** | | |
| *Bulla solida* Gmelin | R | Manual of Conchology, v.15, p.335, pl.37, figs.36-38 |
| *Bulla occidentalis* A. Adams | U | RTA, p.277, pl.26, fig.p |
| **Family Akeridae** | | |
| *Haminoea succinea* (Conrad) | R | P & Sch., p.193, pl.39, fig.283 |
| *Haminoea antillarum* Orbigny | R | W & A, p.142, pl.27, fig.o |
| **Family Scaphandridae** | | |
| *Atys caribaea* (Orbigny) | R | W & A, p.143, pl.27, fig.q |
| **Family Ringiculidae** | | |
| **Ringicula guppyi* Dall | R | Dall, v.3, pt.1, p.14, pl.3, fig.7 |
| **Family Acteonidae** | | |
| *Acteon punctostriatus* (C. B. Adams) | R | W & A, p.140, pl.28, fig.b |
| **Family Acteocinidae** | | |
| *Acteocina bullata* (Kiener) | R | W & A, p.143, pl.27, fig.f |
| *Acteocina canaliculatum* (Say) | U | P & Sch., p.191, pl.39, fig.278 |
| *Acteocina candei* Orbigny | U | W & A, p.143, pl.27, fig.g |
| *Cylichna bidentata* (Orbigny) | R | W & A, p.144, pl.27, fig.c |
| *Retusa sulcata* (Orbigny) | R | RTA, p.280 |
| **Volvula tritica* Olsson & Harbison | R | O & H, p.163, pl.25, figs.3,3a |
| *Volvula oxytata* Bush | R | W & A, p.144, pl.27, fig.d |
| **Family Pyramidellidae** | | |
| *Pyramidella crenulata* (Holmes) | U | P & Sch., p.118, pl.23, fig.154 |
| *Triptychus niveus* Mörch | R | W & A, p.147, pl.28, fig.e |
| *Turbonilla* spp. undet. #1-#7 | R | |
| *Odostomia seminuda* (C. B. Adams) | R | RTA, p.288, text fig.62j |
| **Family Cavolinidae** | | |
| *Creseis acicula* Rang | R | RTA, p.294, text fig.64n |
| *Cavolina longirostris* Lesueur | R | W & A, p.152, text fig.22v |

## Non-Marine Gastropoda
(after Taylor, 1966)

| | | |
|---|---|---|
| **Family Viviparidae** | | |
| *Viviparus georgianus* (Lea) | A | Taylor, p.107, pl.7, fig.3 |
| **Family Ampullariidae (Pilidae)** | | |
| *Pomacea paludosa* (Say) | A | Taylor, p.107, pl.7, fig.8 |
| **Family Hydrobiidae** | | |
| *Notogilla* sp. undet. | A | |
| *Fontigens* sp. undet. | A | |
| **Family Planorbidae** | | |
| *Planorbella* aff. *disstoni* (Dall) | A | Taylor, p.111, pl.8, figs. 10-15 |
| *Planorbella wilsoni* Taylor | R | Taylor, p.111, pl.8, figs.7-9 |
| *Planorbella conanti* (Dall) | C | Dall, p.20, pl.10, figs.1,1a |
| *Planorbella duryi seminole* (Pilsbry) | A | Taylor, p.113, pl.8, figs.4-6 |
| **Family Physidae** | | |
| *Stenophysa meigsii* (Dall) (Juvenile) | R | Taylor, p.110, pl.7, fig.2 |

Family Pupillidae

*Gastrocopta rupicola* (Say) R Pilsbry, 1948, p.905, fig.491

Family Succineidae

*Succinea* sp. undet. R Taylor, p.115

Family Spiraxidae

*Euglandina rosea* (Ferussac) U Taylor, p.109, pl.7, fig.7

Family Bulimulidae

*Bulimus dealbatus* (Say) R Taylor, p.114, pl.7, figs.4-5

Family Polygyridae

*Polygyra* sp. undet. R Taylor, p.115

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June 17, 1970

# RECENT BOOKS

FLUCTUATIONS OF GLACIERS, 1959-1965: A contribution to the International Hydrological Decade, by Peter Kasser. Published by UNESCO and the International Association of Scientific Hydrology, New York and Paris, 1967, iv + 52 pp. text, 25 large tables, 7 folding figures, map in pocket, $6.00

This is the report of study and measurement of glacier variations throughout the world from 1959-1965, a project adopted by the co-ordinating council of the International Hydrological Decade, UNESCO, and combined with a similar project of the International Association of Scientific Hydrology. The brief introductory text is followed by the observed data, presented in tabular form, representing the main body of the report. A large color map of the Aletsch Glaciers (Aletschgletscher), Switzerland, is annexed to the report.

FELDSPARS, by T. F. W. Barth. Published by John Wiley & Sons, Inc., New York, London, Sydney and Toronto, 1969, xi + 261 pp., $14.50

All aspects of the mineralogy of feldspars are covered in this single comprehensible volume with full consideration of new data, concepts and theories from recent significant and spectacular advances in feldspar mineralogy. Determinative methods have been intentionally omitted from this book. General mineralogy and classification of the rock-forming feldspars is followed by a survey of pseudosymmetry and twinning, structures of the feldspars, physical and thermodynamic properties. A brief chapter on the historical development of feldspar terminology concludes the work.

METHODS FOR THE STUDY OF SEDIMENTARY STRUCTURES, by Arnold H. Bouma. Published by John Wiley & Sons, Inc., New York, London, Sydney and Toronto, 1969, xvii + 458 pp., $19.95

This book is a compilation of the many varied techniques used to collect sediment samples and to preserve for study ancient and recent sedimentary structures. The author has arranged the widely varied techniques into convenient groups to facilitate comprehension and selection of the proper technique for each purpose. Each method is described step by step with comparison of the different types and their limitations. The appendices include a list of manufacturers of products and materials needed in the described techniques. An extensive bibliography is included at the end of the volume.

FUNDAMENTALS OF ROCK MECHANICS, by J. C. Jaeger and N. G. W. Cook. Published by Methuen & Co. Ltd., London, 1969, xiv + 513 pp., $19.00

Problems of rock deformation and mechanics are treated in this work primarily for the engineer or designer of excavations and structures in and upon rock. The emphasis of interest is necessarily somewhat different from that of the geologist who is concerned primarily with the origin of geological structures. In recent years, increased need for better knowledge of the mechanical properties of rock has stimulated research in a field which has become known as rock mechanics, here summarized and presented in a single volume for those concerned with the practical aspects of rock properties.

—H.C.S.

# NEW SPECIES OF EOCENE MOLLUSCA FROM THE GULF COAST

JAMES E. ALLEN*
*ALEXANDRIA, LOUISIANA*

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## I. ABSTRACT

Two genera and eight species of gastropods and one bivalve species from the middle and upper Eocene of the Gulf Coast embayment are described as new. The new monotypic genus *Sablea* is the first Eocene assignment within the family Lepetellidae and *Eodaphne*, a new genus in the subfamily Daphnellinae of the family Turridae, is the earliest reported occurrence of a true daphnellid decussated protoconch.

## II. ACKNOWLEDGMENTS

The writer gratefully acknowledges the assistance and cooperation of the following persons: David Dockery III, Jackson, Mississippi, for the contribution of specimens; Gerhard Bakker, Los Angeles City College, for excellent illustrations; Harold E. and Emily H. Vokes, Tulane University, for photography and assistance with plate preparation. Special thanks are due Katherine V. W. Palmer, Paleontological Research Institution, and Harold E. Vokes, Tulane University, for critical review of the manuscript. Their comments and suggestions have been most helpful.

* Research Associate, Paleontological Research Institution.

## III. SYSTEMATIC DESCRIPTIONS

Phylum MOLLUSCA
Class GASTROPODA Cuvier, 1797
Subclass PROSOBRANCHIA
Milne-Edwards, 1848
Order ARCHAEOGASTROPODA Thiele, 1925
Suborder PATELLINA von Ihering, 1876
Superfamily COCCULINACEA Thiele, 1909
Family LEPETELLIDAE Dall, 1881
Genus SABLEA, n. gen.

Type species: *Sablea minuta*, n. sp., upper Eocene, Southern United States.

*Diagnosis*: Shell minute, patelliform, cap-shaped, bilaterally symmetrical. Muscle scar horse-shoe shaped, broadest at anterior ends, open anteriorly. Anterior opening connected by pallial line, impressed in adult specimens, obscure or wanting in immature shells. Apex blunt, posterior in position and curved posteriorly. Aperture narrowly elliptical. Margin not in a single plane, elevated at both ends. Sculpture of growth lines only.

*Discussion*: This curious little shell is somewhat difficult to place since it combines features of several families. It seems to fall most naturally within the Lepetellidae as it has characters of three genera in that group. It combines the saddle-shaped margins of *Tectisumen* Finley, 1927, the blunt, posteriorly placed apex of *Addisonia* Dall, 1882, and the narrow oval aperture of *Cocculinella* Thiele, 1909. It differs from those genera

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by having the impressed pallial line connecting the anterior ends of the muscle scar.

The genus is named for my patient and understanding wife, Sable S. Allen.

SABLEA MINUTA Allen, n. sp.
Plate 2, figs. 1-9

*Description*: Characters as enumerated for the genus and as figured. Anterior slope convex, posterior slope concave. Nucleus not retained. Apex in posterior third of length in mature specimens, not overhanging margin. Shell thin and fragile in juvenile specimens, much thickened in the adult form.

Holotype: PRI 27639.

Dimensions: Length 2.05 mm; width 1.2 mm; height 1.5 mm.

Paratype A: PRI 27640.

Dimensions: Length 1.7 mm; width 1.0 mm; height 1.15 mm.

Paratype B: Author's collection, length 1.6 mm; width .95 mm; height (incomplete) 1.05 mm; not figured.

Type locality: Red River below Montgomery Landing, Grant Parish, Louisiana.

Paratype C: PRI 27641.

Dimensions: Length 3.5 mm; width 1.75 mm; height 2.25 mm.

Locality: Mouth of Saline Bayou, St. Maurice, Winn Parish, Louisiana.

*Occurrence*: Middle Eocene, Cook Mountain Formation, Saline Bayou Member, Claiborne Group. Upper Eocene, Moodys Branch Formation (type), Jackson Group.

*Discussion*: Material available for study in the preparation of this paper consisted of the holotype, an apparently mature individual, two juvenile specimens designated paratypes A and B from the type locality, and one adult specimen from St. Maurice, designated paratype C. In addition to being larger, paratype C differs in two minor features from the holotype. The pallial line is less deeply impressed and the apex is placed relatively more posteriorly.

Examination of the immature specimens shows the apex to be subcentral. Apparently during growth the animal added shell material anteriorly at a more rapid rate than posteriorly with the result that the older specimens have the apex placed progressively more posteriorly. This theory agrees with the slight difference in the location of the apex of two apparently adult individuals of different size as noted above.

This report, so far as is known to the writer, constitutes the first record of the family Lepetellidae below the Miocene.

Order MESOGASTROPODA Thiele, 1925
Superfamily CYCLOPHORACEA Gray, 1847
Family VIVIPARIDAE Gray, 1847
Genus VIVIPARUS Montfort, 1810

Type species by original designation: *V. fluviorum* Montfort (= *Helix vivipara* Linnaeus, 1758) [= *Paludina* Lamarck, *in* Férussac, 1812]. Recent, Europe.

VIVIPARUS ERRONIS Allen, n. sp.
Plate 1, figs. 1-2

*Description*: Shell of about three and one-half whorls, protoconch and outer lip broken. First one and one-half whorls convex with decreasing convexity thereafter. Body whorl flattened below suture with obscure angulation at base. Sutures deeply impressed. Inner lip slightly reflexed over umbilical area leaving a narrow open slit. Aperture higher than wide. No ornamentation except obscure growth lines.

Holotype: PRI 27642.

Dimensions: Height (incomplete) 18 mm; width 14 mm.

Type locality: Red River below Montgomery Landing, Grant Parish, Louisiana.

*Occurrence*: Upper Eocene, Moodys Branch Formation, Jackson Group.

*Discussion*: Since specific differences in this group are largely a matter of degree it is difficult to make comparisons. *V. erronis* seems to be closest to the Paleocene species *V. leai* Meek and Hayden (White, 1883, p. 467, pl. 27, figs. 10-14), from which it differs by having a less convex body whorl, a more elongate aperture and much more deeply impressed sutures.

This species, known only from the type specimen, is noteworthy only by the fact of its occurrence in an otherwise exclusively marine fauna, and it must surely be a vagrant as the name implies. The only other specimen of the genus known from the southern or eastern Eocene is Lyell's specimen [*Viviparus ? lyelli* (Conrad) 1865, p. 32] from the Jackson Group of North Carolina, which is a cast and of somewhat questionable generic identification.

Suborder TAENIOGLOSSA Troschel, 1848
Superfamily CALYPTRAEACEA Lamarck, 1809
Family CAPULIDAE Férussac, 1821
Genus CAPULUS Montfort, 1810

Type species by original designation: *Capulus hungaricus* = *Patella ungarica* Lin-

naeus. Recent: Europe, North America; Miocene-Pleistocene, Europe.

### Capulus cassis Allen, n. sp.
Plate 1, figs. 3-4

*Description*: Muscle scars typical of the genus. Shell dome-shaped, flared at the margins. Protoconch spiral, minute, posterior to midline and situated behind the apex. Sculpture of growth lines with a few obscure radial striations at the posterior margin. Aperture broadly oval.

Holotype: PRI 27643.

Dimensions: Length (incomplete) 15 mm; width 13 mm; height 6 mm.

Type locality: Red River below Montgomery Landing, Grant Parish, Louisiana.

*Occurrence*: Upper Eocene, Moodys Branch Formation, Jackson Group.

*Discussion*: *C. cassis* does not closely resemble any species known to the writer. The domed-shape, regularly flared margins and barely perceptible protoconch will serve to separate it from other Tertiary forms.

The species is known only from the holotype. Although possibly an unseemly comparison, to the writer this shell instantly recalls the helmet worn by a French 'poilu' during World War I.

Superfamily Tonnacea Suter, 1913
Family Cymatiidae Iredale, 1913
Genus Colubraria Schumacher, 1817

Type species by monotypy: *Colubraria granulata* Schumacher (= *Murex maculosus* Gmelin). Recent, Philippines.

### Colubraria vokesae Allen, n. sp.
Plate 2, figs. 10-11

*Description*: The holotype seems to be an immature specimen but the adult characters are well shown. Small for the genus. Shell consists of about five whorls; slender with elongate body whorl. Nucleus of three whorls; the first depressed making the apex blunt, the following two rapidly enlarging, smooth, bulbous. Fully developed adult sculpture begins abruptly, consisting of close set, narrow axial ribs crossed by flat spirals, eight on the whorls of the spire, weakly nodular at the intersections. Spaces between spirals crowded by microscopic threads that cross the axial ribs and varices. Varices are narrow but strong, rising above the sutures and occurring every ⅔ whorl after initiation of the adult sculpture. Varix at aperture set behind outer lip. Axial ribs become obsolete anteriorly on body whorl. Aperture narrow, one-half total shell height; this proportion, however, may be due to the immaturity of the specimen. Outer lip weakly and irregularly denticulate at inner edge. Parietal shield elevated to form a collar that is horizontally striated on the outer face. Canal short, recurved at termination. Columella slightly keeled at canal with one weak oblique plait above.

Holotype: PRI 27644.

Dimensions: Height 5 mm; width 2 mm.

Type locality: Red River below Montgomery Landing, Grant Parish, Louisiana.

*Occurrence*: Upper Eocene, Moodys Branch Formation, Jackson Group.

*Discussion*: This constitutes the first report of the genus from the southern Eocene. Tucker and Wilson (1932, p. 49, pl. 8, figs. 3, 4; 1933, p. 70, pl. 11, fig. 14) figured two species from Florida Neogene formations but neither are close to *C. vokesae*. In particular the small size and large bulbous nuclear whorls will serve to separate these species.

Known only from the holotype.

Named for Emily H. Vokes, Tulane University, who has been an unfailing source of help.

Order Stenoglossa Bouvier, 1887
Superfamily Buccinacea Latreille, 1825
Family Fasciolaridae Chenu, 1859
Genus Latirus Montfort, 1810
Subgenus Polygona Schumacher, 1817

Type species by monotypy: *Polygona fusiformis* Schumacher (= *Murex infundibulum* Gmelin). Recent, West Indies.

### Latirus (Polygona) vokesi Allen, n. sp.
Plate 1, figs. 5-7

*Description*: Shell fusiform, slender, medium-sized, anomphalous. Aperture small, canal elongate, oblique, anterior end missing. Total of about eleven whorls including four and one-half in elevated nucleus. First two and one-half nuclear whorls smooth, conical; succeeding two whorls with axial ribs becoming increasingly coarse to the beginning of the adult sculpture. Adult sculpture of seven prominent swollen axial ribs crossed by three strong spirals with a fourth weaker spiral added on later whorls just above the suture. The primary spirals increase in strength as they cross the ribs. Secondary spirals consist of three strong threads in each interspace, the middle one slightly more prominent. The secondary spirals begin on the first post-nuclear whorl as a single thread, a second is added and by the end of the third post-nuclear whorl the three threads are visible, which persist through the body whorl. Sutures slightly impressed, sinuous. The axial ribs are interrupted at the sutures giving the appearance of a deep sutural area. A noticeable feature of the

sculpture is that the successive axial ribs do not reach the position of the corresponding ribs in the whorl immediately above so that each line of ribs forms a receding curve down the spire.

Edge of outer lip lamellar, the rim scalloped by the spirals, inner margin fluted. Parietal callus heavy, slightly separated at edge along canal. A small tooth or constriction at the beginning of the canal is set well inside aperture. Columella with three plaits of approximately equal strength. Parietal ridge at posterior end of aperture.

Holotype: PRI 27645.

Dimensions: Height (incomplete) 17.5 mm; width 7.5 mm.

Type locality: Mouth of Saline Bayou, St. Maurice, Winn Parish, Louisiana.

*Occurrence*: Middle Eocene, Cook Mountain Formation, Saline Bayou Member, Claiborne Group.

*Discussion*: *Latirus vokesi* is closest to another Claiborne species, *L. sexcostatus* Johnson, particularly a mature specimen such as figured by Palmer (1937, pl. 54, fig. 3). *L. vokesi* may be distinguished by the three strong primary striations that are present from the first post-nuclear whorl, while a third is present only on the later whorls of *L. sexcostatus*. Additionally, as noted above, the ribs of *L. vokesi* form a descending, receding line while those of *L. sexcostatus* are in alignment on the whorls of the spire.

The nuclear whorls of *L. vokesi* are of particular interest in that there are two complete whorls with curved riblets prior to the beginning of the adult sculpture, (see Pl. 1, fig. 7). The common condition within the genus is the presence of a few such ribs for one-half whorl or less. This form, therefore, varies in this respect from any other southern Eocene species, and in fact from any species that has come to this writer's attention.

Named for Harold E. Vokes, Tulane University, to whom all paleontologists in this field owe a tremendous debt for his monumental work on bivalve nomenclature.

## Family TURRIDAE Swainson, 1840 (emended)
## Subfamily TURRINAE Powell, 1942
## Genus SINISTRELLA Meyer, 1887

Type species by subsequent designation, Cossmann, 1896; *Triforis americanus* Aldrich, 1885. Eocene, southern United States.

### SINISTRELLA MEYERI Allen, n. sp.
### Plate 2, figs. 12-15

*Description*: Shell sinistral, small, turreted, solid. Whorls about nine, including a smooth mammillated nucleus of one and one-half to two whorls. Primary sculpture consists of two spiral cords; one subsutural, the second and strongest just below the center of the whorls. Secondary spirals are added on later whorls, generally a strong thread below the center carina and a third cord just above the suture. Body whorl has eight to ten spiral cords with occasional intermediate threads. Strong growth lines on the body whorl behind the aperture incise and dominate the spirals in that area. Sutures linear, indistinct on the early whorls. Aperture narrowly ovate, canal short and oblique. The outer lip is not entire in any specimen seen but it seems to be sharp as in the type species. Plications within outer lip set back from edge. Sinus shallow, set on the primary central carina.

Holotype: PRI 27647.

Dimensions: Height 12.5 mm; width 4.5 mm.

Paratype: PRI 27648.

Dimensions: Height 10.5 mm; width 4 mm.

→

## PLATE 1

Figures — Page

1-2. *Viviparus erronis* Allen, n. sp. ---- 70
Holotype, PRI 27642, × 2
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10-13. *Plicatula creola* Allen, n. sp. ---- 77
13-14. Holotype, Right valve, PRI 27651, × 2
15-16. Paratype, Left valve, PRI 27652, × 2

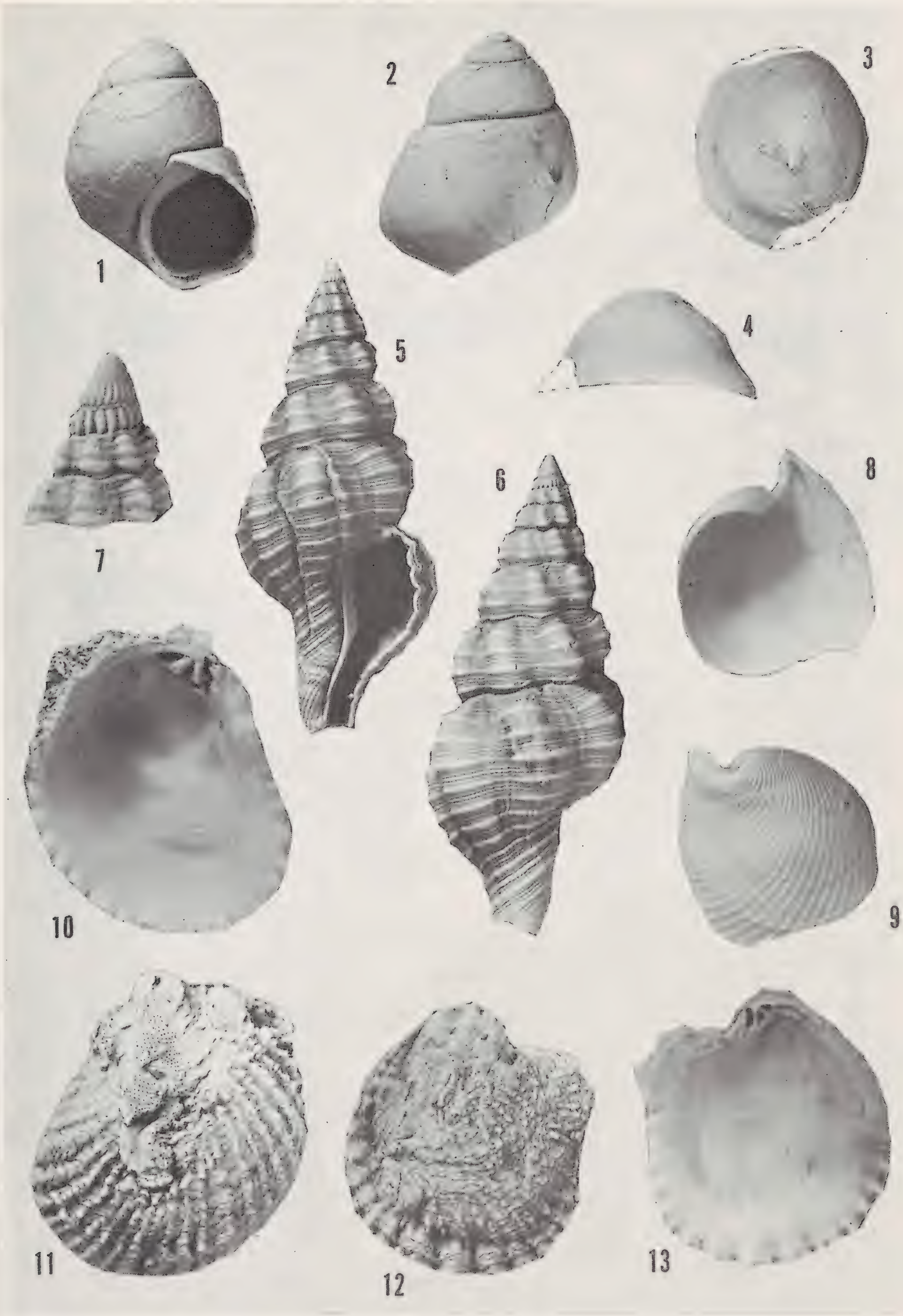


PLATE 1

Type locality: Red River below Montgomery Landing, Grant Parish, Louisiana.

*Occurrence*: Upper Eocene, Moodys Branch Formation, Jackson Group.

*Discussion*: This addition of a second species to the genus should serve to strengthen the validity of the genus described by Meyer which some authors have felt was merely a sinistral *Trypanotoma.*

*S. meyeri* differs from *S. americana* in the character of the spiral ornamentation. *S. americana* has a wide beaded or nodular central carination that usually becomes binodular within a few whorls. *S. meyeri* has one central smooth cord that is much more narrow. The whorls of *S. americana* are excavated at their base, making the suture distinct. This condition is not present in *S. meyeri.*

An examination of the sinus is, to the author, the most interesting point of comparison. Meyer's statement, "Obwohl ein eigentlicher Sinus nicht vorhanden ist, - - - - -", (1887, p. 18) in his description of the genus is technically correct but somewhat misleading. In a perfect specimen of *S. americana* the sinus, as indicated by the growth lines, although shallow, is readily apparent and is centered on the upper half of the central binodular carination. The subcentral cord on the whorls of *S. meyeri* is equal in position to the lower half of the binodular spiral of *S. americana.* Since the sinus of *S. meyeri* is set on that subcentral cord the relative location of the sinus differs slightly in the two species, although identified in both with the primary peripheral carination.

Named for Otto Meyer, the author of the genus, who made important contributions to Gulf Coast paleontology near the end of the last century.

## Subfamily DAPHNELLINAE Hedley, 1922

### Genus EODAPHNE, n. gen.

Type species: *Eodaphne powelli*, n. sp., upper Eocene, southern United States.

*Diagnosis*: Shell minute. Protoconch multispiral, rapidly enlarging with succeeding whorls becoming increasingly convex. First whorl bulbous, translucent. Succeeding nuclear whorls decussated with tendency to nodulation at the intersections of the oblique threads. Adult sculpture consists of spiral threads; the first strong spiral below the suture forms a weak shoulder on the whorls of the teleconch. Sinus sutural, occupying the shoulder area which is weakly concave. Body whorl convex below the sinus, anterior canal moderately long, slightly curved.

*Discussion*: *Eodaphne* has an unmistakable daphnellid protoconch and sinus. It appears to be intermediate between *Daphnella* Hinds, 1844, and *Cryptodaphne* Powell, 1942. It is separated from *Daphnella* by the primary adult sculpture which consists solely of spiral threads. The protoconch and spiral ornamentation are closer to *Cryptodaphne* from which it is separated by the absence of a strong keel on the teleconch, lack of constricted aperture and the sinus, although deeper, is not as wide. The shoulder of *Eodaphne* occupies much less space on the body whorl than in *Cryptodaphne.*

→

PLATE 2

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1-9. *Sablea minuta* Allen, n. gen., n. sp. ---- 70
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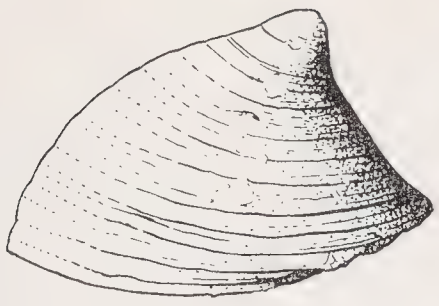
16-17. Holotype, PRI 27649, × 12
18. Holotype, nuclear whorls, × 60



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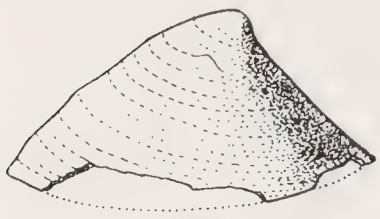

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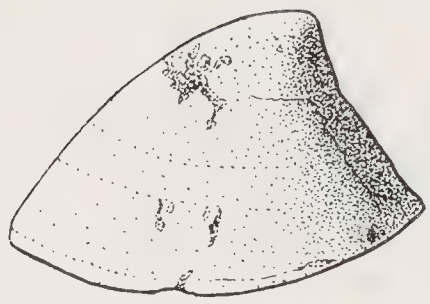

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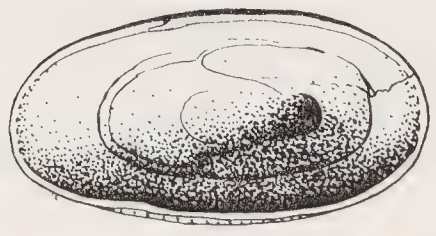

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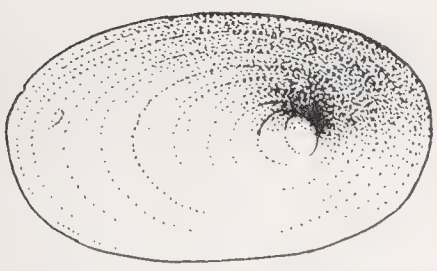

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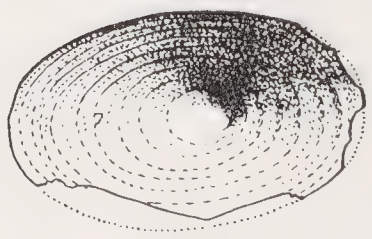

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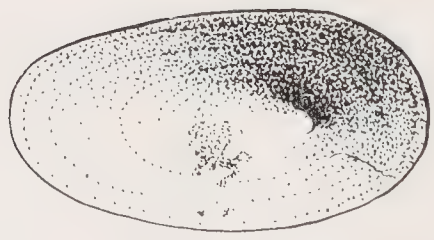

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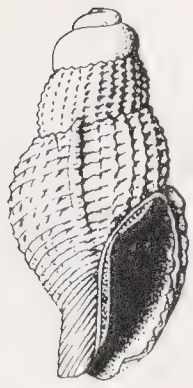

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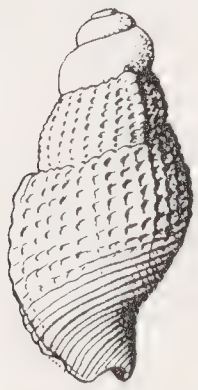

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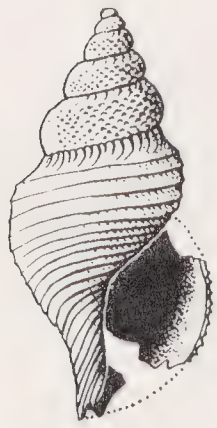

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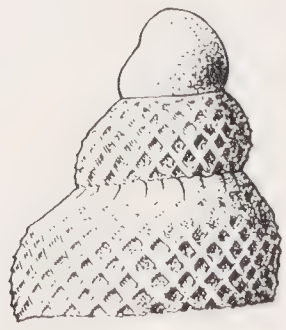

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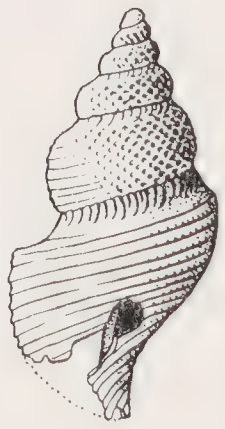

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PLATE 2

### Eodaphne powelli Allen n. sp.

Plate 2, figs. 16-18

*Description*: Characters as enumerated for the genus and as figured. Shell consists of about six whorls of which five constitute the nucleus. First one and one-half whorls are bulbous, translucent and microscopically granular. Succeeding three and one-half whorls decussated by oblique threads, nodular at the intersections. The sinus is visible on the last two nuclear whorls and is marked by a slight concavity below the suture. Adult sculpture begins abruptly without any varix or other demarcation. Ornamentation consists of flat, irregularly placed spiral threads with wider interspaces that are minutely granulated. Sinus area marked with growth lines only. Sutures linear, somewhat obscured by the sinus. Outer lip and end of canal broken. Anterior canal moderately long. Aperture less than one-half total shell height. Shell thin and fragile.

Holotype: PRI 27649.

Dimensions: Height (incomplete) 2.3 mm; width 1.2 mm.

Type locality: Red River, South of Montgomery Landing, Grant Parish, Louisiana.

*Occurrence*: Upper Eocene, Moodys Branch Formation, Jackson Group.

*Discussion*: Recent species within the subfamily Daphnellinae are numerous and widely distributed with several genera represented in American waters. It is, therefore, somewhat surprising that the fossil record should be so incomplete. One possible conclusion, as noted by Powell (1942, p. 173), is that it is a lately developed family, although his comment applied only to the New Zealand fauna.

At present the Gulf Coast Eocene is represented by three species: *Daphnella gregorioi* (Cossmann), *Daphnella imperita* Harris, and *Daphnella quindecima* Harris (Harris, 1937, pp. 74-75: pl. 13, figs. 7-10; Palmer and Brann, 1966, pp. 628-629); all from the middle Eocene, Claiborne Group. All three, however, lack the diagonally cancellated protoconch of *Daphnella s.s.* and should be reinvestigated in the light of later classification of the Turrinae.

*Eodaphne powelli* represents, so far as is known to the writer, the first report of the occurrence of the true daphnellid protoconch below the Miocene. This new species is known only from a single, apparently immature specimen.

Named for A. W. B. Powell, Auckland Institute and Museum, New Zealand, to honor his outstanding work on the Turridae.

Subclass Opisthobranchia
Milne-Edwards, 1848
Order Tectibranchiata Cuvier, 1817
Suborder Cephalaspidea Fischer, 1883
Superfamily Philinacea Fischer, 1883
Family Philinidae Fischer, 1883
Genus Philine Ascanius, 1772
Subgenus Megistostoma Gabb, 1864

Type species by monotypy: *Megistostoma striata* Gabb (= *Bullacea gabbiana* Stoliczka). Middle Eocene, California.

### Philine (megistostoma) dockeryi Allen, n. sp.

Plate 1, figs. 8-9

*Description*: Shell broadly ovate, thin and fragile. Aperture large with widely expanded outer lip. Posterior extremity of outer lip produced with strong convexity in the umbilical area. Anterior margin broadly rounded. Spire concealed by callus pad. Callus on inner lip irregularly striated longitudinally, strongest anteriorly.

Holotype: PRI 27650.

Dimensions: Height to apex (incomplete) 14 mm; maximum width 14.5 mm. The holotype was broken during photography.

Type locality: Riverside Park behind swimming pool, Hinds County, Jackson, Mississippi.

*Occurrence*: Upper Eocene, Moodys Branch Formation, Jackson Group.

*Discussion*: The holotype does not exhibit any scars but one specimen in the author's collection shows a deep muscle attachment scar near the margin of the outer lip just below the mid-line. This character must be highly variable within the species as it seems to be within the genus.

Sculpture of concentric, elevated, twin striae similar to the type species of the subgenus, *M. gabbianum* (Vokes, 1939, Pl. 17, figs. 1-3), which it most closely resembles. *M. dockeryi* may be distinguished by its more conspicuous ribs and much wider interspaces.

Named for David Dockery III, Jackson, Mississippi, the collector.

Class Bivalvia* Linnaeus, 1758
Subclass Pterimorphia Beurlen, 1944
Order Pterioida Newell, 1965
Suborder Pteriina Newell, 1965
Superfamily Pectinacea Rafinesque, 1815

---

* Bivalve nomenclature after Vokes, 1967.

Family PLICATULIDAE Watson, 1930

Genus PLICATULA Lamarck, 1801

Type species by subsequent designation, Gray, 1841, *Plicatula gibbosa* Lamarck (= *P. ramosa* Lamarck). Recent, West Indies.

PLICATULA CREOLA Allen, n. sp.

Plate 1, figs. 10-13

*Description*: Shell medium in size, ovate to nearly circular in shape, strongly inflated. Attachment area medium, covering about one-third of the lower valve in the holotype, a right valve. Hinge structure normal for the genus and quite strong. Sockets in the right valve indicate that the cardinals of the left valve are the larger and diverge at such an angle that separation of the two valves without damage would be difficult or impossible. This is borne out in that both hinge teeth are broken in the two left valves available for study. Lower valve more or less regularly inflated, shallower near the posterior and ventral margins but without a flattened marginal area. Margins weakly folded. Upper valve has a strongly inflated central disk with flattened, strongly folded margins. Posterior margin of left valve alated. Adductor muscle scars prominent, posterior to center line. Pallial line simple, not impressed. External sculpture consists of sharp, narrow, radial ribs with larger interspaces. Scales on ribs minutely spinose, strongest dorsally. Central disk of upper valve exhibits typical but weaker fine ribbing over most of surface, becoming coarser at the flattened marginal areas.

Holotype: Right valve, PRI 27651.
Dimensions: Height 22.5 mm; width 20 mm.
Paratype: Left valve, PRI 27652.
Dimensions: Height 19 mm; width 18.5 mm.

Type locality: Red River, South of Montgomery Landing, Grant Parish, Louisiana.

*Occurrence*: Upper Eocene, Moodys Branch Formation, Jackson Group.

*Discussion*: *P. creola* does not closely resemble any known American form of *Plicatula*. The fine ribbing and strong inflation separates it from other Eocene species of the genus. The sculpture somewhat resembles *P. filamentosa planata* Aldrich (Harris, 1919, pl. 12, fig. 17) but is stronger and more regular and *P. creola* has no trace of the internal radii that are the trademark of *P. filamentosa* stock.

Named after the type locality, which was once known as Creole Bluff.

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June 17, 1970

# *SPHENASTER*, NEW GENUS, A PLIOCENE CALCAREOUS NANNOFOSSIL FROM THE TROPICAL INDO-PACIFIC

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## I. Abstract

A distinctive new calcareous nannoplankton taxon from the early Pliocene interval of a tropical Indo-Pacific deep-sea core is described as a new genus and species, *Sphenaster metula*.

## II. Introduction

During a study of Pliocene calcareous nannoplankton from a series of tropical Indo-Pacific deep-sea cores, collected by the Scripps Institution of Oceanography, a previously undescribed taxon has been observed to occur consistently in the early Pliocene interval. Other authors may have referred to it previously as *Sphenolithus* sp. or *Sphenolithus* cf. *S. abies* in samples of the same age. Description of this new form is based on study with the light microscope and the transmission and scanning electron microscopes. The types are temporarily deposited in the collections of Chevron Oil Field Research Company, La Habra, California. Appreciation is expressed to Dr. Helen Tappan Loeblich for critical reading of the manuscript.

→

## Plate 1

Figures

1-8 *Sphenaster metula* Wilcoxon, n. sp. (Figs. 1-4 from light microscope, Figs. 5-8 from transmission electron microscope), (1) plan view, × 2700, (2) crossed nicols, (3) plan view, × 5400, (4) crossed nicols, (5) tilted specimen, × 18,000, (6) distal view of specimen between rays of discoaster, × 12,000, (7) distal view of specimen with central hole plugged, × 18,000, (8) distal view of specimen with central hole open, × 16,000.

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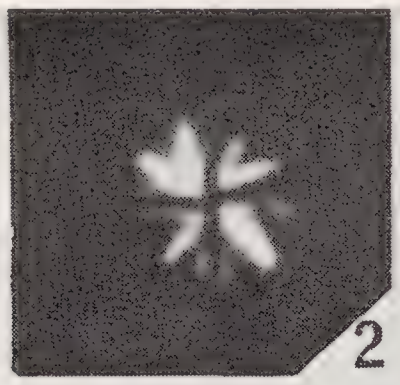
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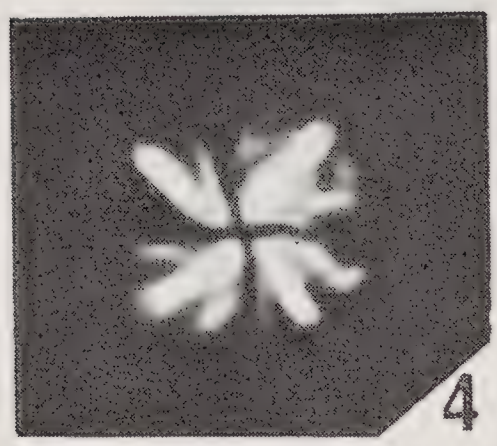
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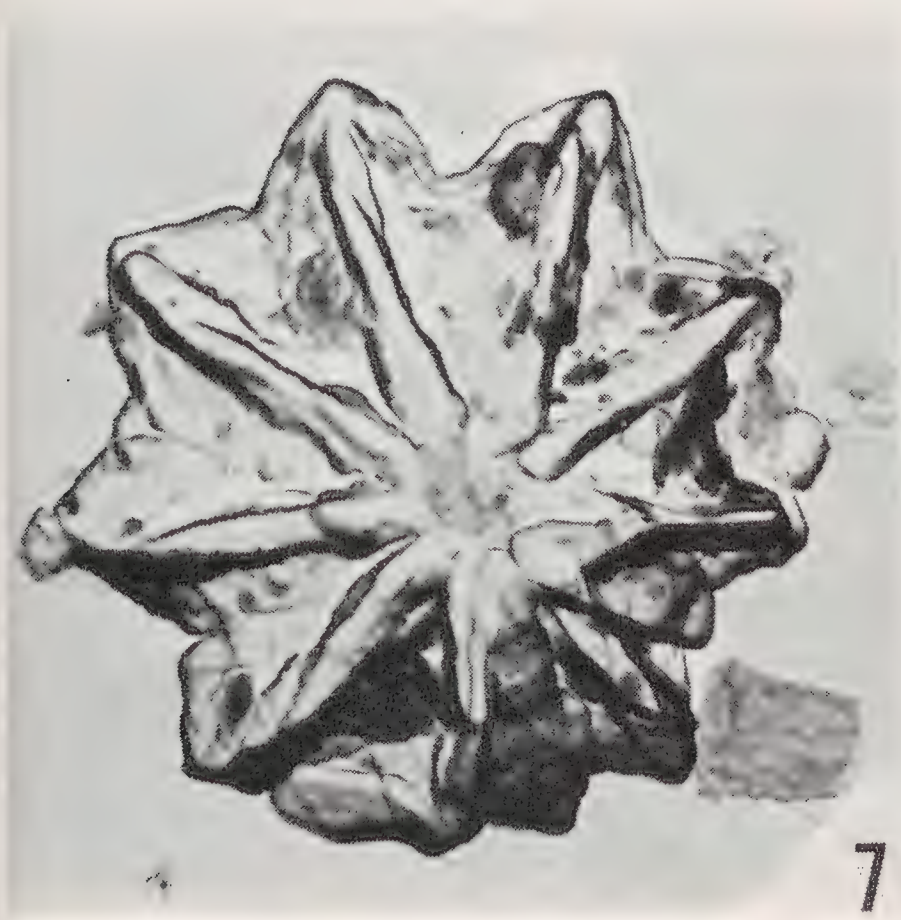
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PLATE 1

## III. Systematic Paleontology

### Incertae Sedis

### Genus Sphenaster Wilcoxon, n. gen.

*Diagnosis*: Small, concavo-convex, sphenolith-like form, petaloid in plan view. Thickened elements radiate from an open central area and are joined throughout most of their length. As viewed from the side, each element tapers pyramidally from the base to the top.

*Type species*: *Sphenaster metula,* Wilcoxon, n. sp.

*Remarks*: *Sphenaster* differs from *Sphenolithus* in presenting a uniformly symmetrical extinction pattern between crossed nicols and by the presence of a hole through the center. It differs from *Discoaster* in not being a single unit of calcite.

### Sphenaster metula, Wilcoxon, n. sp.

Pl. 1, figs. 1-8; Pl. 2, figs. 1-6

*Description*: Small (2-4 $\mu$) petaloid form composed of 8-10 elements which radiate outward from a central opening. In some individuals this perforation is closed, presumably by secondary calcification. Individual elements broaden distally from the central hole for about half their length, then narrow to a bluntly pointed tip. On the concave side, regarded as proximal, the sutural lines between the elements are sinuously curved; this sinuosity is not apparent on the convex, or distal side. On the dorsal surface a blunt ridge extends from the tip ends of each element upwards to their culmination at the open central area.

*Remarks*: Because of its very small size, the morphology of this species becomes clear only with the electron microscope. Although quite distinctive in polarized light, it may be mistaken for a species of *Sphenolithus*, as it strongly resembles an intermediate between a sphenolith and a discoaster.

The specific name is from the Latin *metula*, meaning small pyramid.

*Age and Occurrence*: All specimens figured are from the Scripps Institution of Oceanography, Indian Ocean deep-sea core DODO 57P, from 15° 40′ S. lat., 112° 44′ E. long., at 3660 m., depth in core 107-109 cm. The type level for this species is zone N. 19 (early Pliocene) of Banner and Blow (1965). It also has been observed in other Indo-Pacific deep-sea cores in the same zone.

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June 17, 1970

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## Plate 2

Figures

1-6 *Sphenaster metula* Wilcoxon, n. sp. (all figures from scanning electron microscope), (1) paratype, distal view, specimen tilted 45°, × 18,000, (2) same specimen tilted 70° showing side view, × 16,000, (3) paratype, proximal view, specimen tilted 45°, × 18,000, (4) same specimen as Fig. 3, proximal view, × 18,000, (5) paratype, distal view, × 20,000, (6) holotype, distal view, × 18,000.

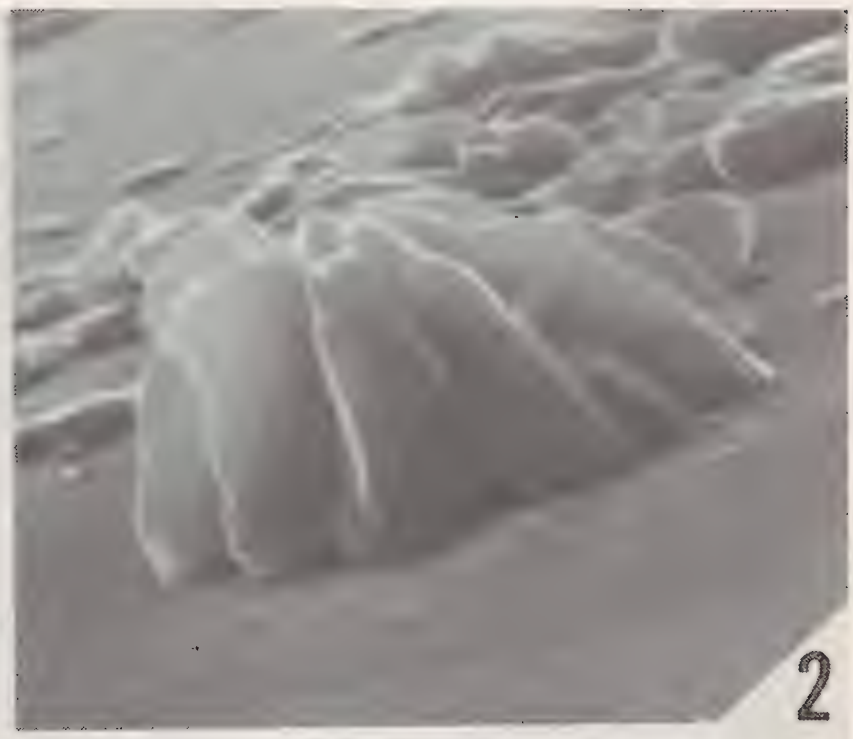

PLATE 2

# *CYCLOCOCCOLITHINA* WILCOXON *NOM. NOV.* (NOM. SUBST. PRO *CYCLOCOCCOLITHUS* KAMPTNER, 1954)

JAMES A. WILCOXON

*CHEVRON OIL FIELD RESEARCH COMPANY, LA HABRA, CALIFORNIA*

The type species of *Cyclococcolithus* Kamptner, 1954, was originally described by Murray and Blackman, 1898, and placed in the then invalid genus *Coccosphaera*. The new species was named *Coccosphaera leptopora*, later to be designated type by Hay, 1966. Kamptner, 1954, erected the new genus *Cyclococcolithus* but failed to designate a type and included with it *Umbilicosphaera mirabilis* Lohmann, 1902, which was already the type species of that genus. Kamptners inclusion of the type of another genus in the new genus *Cyclococcolithus* resulted in the name *Cyclococcolithus* being nomenclaturally superfluous and, therefore, illegitimate and unavailable for use (I.C.B.N. Art. 63).

The following species have been validly described under *Cyclococcolithus* and are here included under the new genus *Cyclococcolithina*:

*Cyclococcolithina acclinis* (Levin & Joerger) Wilcoxon n. comb., = *Cyclococcolithus acclinis* Levin & Joerger, 1967, Micropaleontology, v. 13, p. 166, pl. 1, fig. 13a-b.

*Cyclococcolithina aequiscutum* (Gartner) Wilcoxon n. comb., = *Cyclococcolithus aequiscutum* Gartner, 1967, Univ. Kansas Paleont. Contr., Paper 28, p. 4, pl. 7, fig. 4.

*Cyclococcolithina anulata* (Reinhardt) Wilcoxon n. comb., = *Cyclococcolithus anulatus* Reinhardt, 1966, Monatsber. Deutsch. Akad. Wiss. Berlin, v. 8, p. 520, pl. 1, figs. 3, 4, text-fig. 2.

*Cyclococcolithina astropora* (Stradner) Wilcoxon n. comb., = *Cyclococcolithus astroporus* Stradner, 1963, Sixth World Petr. Congr., sect. 1, paper 4, p. 75, pl. 9, figs. 5-7, text-figs. 3 (2a, b).

*Cyclococcolithina atremata* (Kamptner) Wilcoxon n. comb., = *Cyclococcolithus atrematus* Kamptner, 1967, Ann. Naturhist. Mus. Wien, v. 71, p. 128, pl. 3, figs. 22, 23.

*Cyclococcolithina bollii* (Roth) Wilcoxon n. comb., = *Cyclococcolithus bollii* Roth, 1969, Eclogae Geol. Helv., v. 61 (1968), p. 465, pl. 1, figs. 3, 4; text-figs. 1-3.

*Cyclococcolithina cricota* (Gartner) Wilcoxon n. comb., = *Cyclococcolithus cricotus* Gartner, 1967, Univ. Kansas Paleont. Contr., Paper 20, p. 5, pl. 7, fig. 7.

*Cyclococcolithina decora* (Kamptner) Wilcoxon n. comb., = *Cyclococcolithus decorus* Kamptner, 1963, Ann. Naturh. Mus. Wien, v. 66, p. 163, text-fig. 19.

*Cyclococcolithina dictyoda* (Deflandre & Fert) Wilcoxon n. comb., = *Discolithus dictyodus* Deflandre & Fert, 1954, Ann. Paléont., v. 40, p. 140, text-figs. 15, 16.

*Cyclococcolithina elata* (Kamptner) Wilcoxon n. comb., = *Cyclococcolithus elatus* Kamptner, 1956, Anz. Österr. Akad. Wiss., Math.-Naturw. Kl., v. 93, p. 10.

*Cyclococcolithina formosa* (Kamptner) Wilcoxon n. comb., = *Cyclococcolithus formosus* Kamptner, 1963, Ann. Naturh. Mus. Wien, v. 66, p. 163, pl. 2, fig. 8, text-fig. 20.

*Cyclococcolithina fragilis* (Lohmann) Wilcoxon n. comb., = *Coccolithophora fragilis* Lohmann, 1912, Veröff. Inst. Meeresk. Univ. Berlin, N.F., Geogr.-Naturw. Reihe, v. 1, pp. 49, 54, text-fig. 11.

*Cyclococcolithina gammation* (Bramlette & Sullivan) Wilcoxon n. comb., = *Coccolithites gammation* Bramlette & Sullivan, 1961, Micropaleontology, v. 7, p. 152, pl. 7, figs. 7a-c, 14a, b.

*Cyclococcolithina humilis* (Kamptner) Wilcoxon n. comb., = *Cyclolithus humilis* Kamptner, 1956, Anz. Österr. Akad. Wiss., Math.-Naturw. Kl., v. 93, p. 9.

*Cyclococcolithina inversa* (Deflandre) Wilcoxon n. comb., = *Cycococcolithus leptoporus* var. *inversus* Deflandre *in* Deflandre & Fert, 1954, Ann. Paléont., v. 40, p. 150, pl. 9, figs. 4-7.

*Cyclococcolithina leptopora* (Murray & Blackman) Wilcoxon n. comb., = *Coccosphaera leptopora* Murray & Blackman, 1898, Philos. Trans. Roy. Soc. London 190 B, pp. 430, 439, pl. 15, figs. 1-7.

*Cyclococcolithina luminis* (Sullivan) Wilcoxon n. comb., = *Cyclococcolithus luminis* Sullivan, 1965, Univ. Calif. Publ. Geol. Sc. 53, p. 33, pl. 3, figs. 9a, b.

*Cyclococcolithina lusitanica* (Black) Wilcoxon n. comb., = *Coccolithus lusitanicus* Black, 1964, Palaeontology, v. 7, p. 308, pl. 50, figs. 1, 2.

*Cyclococcolithina margaritae* (Roth & Hay) Wilcoxon n. comb., = *Cyclococcolithus margaritae* Roth & Hay *in* Hay, Mohler, Roth, Schmidt & Boudreaux, 1967, Trans. Gulf Coast Assoc. Geol. Soc., v. 17, p. 446, pl. 6, fig. 9.

*Cyclococcolithina minuta* (Kamptner) Wilcoxon n. comb., = *Cyclococcolithus minutus* Kamptner, 1963, Ann. Naturh. Mus. Wien, v. 66, p. 165, text-fig. 22.

*Cyclococcolithina multistriata* (Kamptner) Wilcoxon n. comb., = *Cyclococcolithus multistriatus* Kamptner, 1963, Ann. Naturh. Mus. Wien, v. 66, p. 165, text-fig. 23.

*Cyclococcolithina neogammation* (Bramlette & Wilcoxon) Wilcoxon n. comb., = *Cyclococcolithus neogammation* Bramlette & Wilcoxon, 1967, Tulane Stud. Geol., v. 5, p. 104, pl. 1, figs. 1-3; pl. 4, figs. 3-5.

*Cyclococcolithina orbis* (Gartner & Smith) Wilcoxon n. comb., = *Cyclococcolithus orbis* Gartner & Smith, 1967, Univ. Kansas Paleont. Contr., Paper 20, p. 4, pl. 4, figs. 1-3.

*Cyclococcolithina pertusa* (Sullivan) Wilcoxon n. comb., = *Coccolithus pertusus* Sullivan, 1965, Univ. Calif. Publ. Sc. 53, p. 32, pl. 3, figs. 5a, b, 6a, b.

*Cyclococcolithina pirocena* (Kamptner) Wilcoxon n. comb., = *Cyclococcolithus pirocenus* Kamptner, 1967, Ann. Naturhist. Mus. Wien, v. 71, p. 129, pl. 4, fig. 25.

*Cyclococcolithina reticulata* (Gartner & Smith) Wilcoxon n. comb., = *Cyclococcolithus reticulatus* Gartner & Smith, 1967, Univ. Kansas Paleont. Contr., Paper 20, p. 4, pl. 5, figs. 1-4.

*Cyclococcolithina rotula* (Kamptner) Wilcoxon n. comb., = *Cyclococcolithus rotula* Kamptner, 1956, Anz. Österr. Akad. Wiss., Math.-Naturw. Kl., v. 93, p. 10.

*Cyclococcolithina spatiosa* (Kamptner) Wilcoxon n. comb., = *Cyclococcolithus spatiosus* Kamptner, 1963, Ann. Naturk. Mus. Wien, v. 66, p. 166, text-fig. 24.

*Cyclococcolithina waxahachia* (Bukry) Wilcoxon n. comb., = *Cyclococcolithus*? *waxahachia* Bukry, 1969, Univ. Kansas Paleont. Contr., Art. 51 (Protista 2), p. 30, pl. 9, fig. 10.

June 17, 1970

# NOTES ON CANCELLARIIDAE (MOLLUSCA: GASTROPODA)—II

RICHARD E. PETIT*
*OCEAN DRIVE BEACH, SOUTH CAROLINA*

This is the second of a series of papers dealing with various aspects of the gastropod family Cancellariidae (Volutacea). In this paper one new genus is described, together with two new species from the Tertiary of the southeastern United States and two new species of Recent Cancellariidae from the Galápagos Islands. In addition, new names are proposed for two previously described species, one from off the Cape of Good Hope, and the other from Kerguelen Island, southern Indian Ocean.

## OLSSONELLA Petit, n. gen.

Type, here designated: *Cancellaria smithii* Dall, 1888, Recent, Western Atlantic.

*Description*: Shell scalate, with corded varices, the outer lip arched, internally lirate; columella with two plications; shallow anterior notch; umbilicus may be present in varying degrees, differing even in the same species between juvenile and adult specimens; nepionic whorls smooth, polished, about 2½ in number, sutures very deep; aperture ovate-trigonal.

*Discussion*: Shells of this new genus would appear to be similar to figures in the literature of species of *Sveltella* Cossmann, 1889, of the Eocene of Europe, but actual comparison shows many differences, the primary distinction being the scalate form of *Olssonella,* its deeper sutures and the invariable presence of spiral cords.

The following species are considered to belong to *Olssonella*:

*Olssonella vokesae* Petit, n. sp. (Silverdale, North Carolina; early lower Miocene).

*Cancellaria desmotis* Gardner, 1937 (U. S. Geol. Surv. Prof. Paper 142-F, p. 373, pl. 45, fig. 5; Chipola Formation, Florida; late lower Miocene).

*Cancellaria bifoliata* Aldrich, 1903 (Nautilus, v. 16, p. 101, pl. 4, fig. 24; Oak Grove Sand, Florida; late lower Miocene).

*Cancellaria (Trigonostoma) sphenoidostoma* Gardner, 1937 (U. S. Geol. Surv. Prof. Paper 142-F, p. 376, pl. 45, figs. 11, 12; Shoal River Formation, Florida; middle Miocene).

undescribed species (Gatun Formation, Canal Zone; middle Miocene).

*Cancellaria scalatella* Guppy, 1873 (Proc. Sci. Assoc. Trinidad, v. 2, p. 78, pl. 2, fig. 4; Bowden Formation, Jamaica; upper Miocene).

*Trigonostoma thisbe* Olsson, 1964 (Neogene Moll. Northwestern Ecuador, p. 126, pl. 22, fig. 6; Esmeraldas Formation, Ecuador; Mio-Pliocene).

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species cf. *smithii* Dall (Waccamaw Formation, South Carolina; Pliocene).
species cf. *smithii* Dall (Moín Formation, Port Limón, Costa Rica; Pleistocene).
*Cancellaria smithii* Dall, 1888 (*in* Agassiz, Three Cruises of *Blake*, p. 70, fig. 292; Recent, Western Atlantic).
*Cancellaria funiculata* Hinds, 1843 (Proc. Zool. Soc. London, pt. 11, p. 48; Recent, Panamic-Pacific).
*Trigonostoma campbelli* Shasky, 1961 (Veliger, v. 4, p. 20, pl. 4, fig. 5; Recent; Panamic-Pacific).

These southeastern U. S., Panamic, and Jamaican fossils, and the Recent (North Carolina to Gulf of Mexico) *O. smithii* (Dall), with the two Recent Panamic-Pacific species form a compact, well-defined group. *Olssonella vokesae* has only a faint umbilical chink, as does the type of the new genus. In the Miocene of Florida there are species that are openly umbilicate, as are the two Recent Panamic-Pacific species *O. funiculata* (Hinds) and *O. campbelli* (Shasky).

The genus is named for Mr. Axel A. Olsson, who has contributed so much to our knowledge of the Tertiary faunas of the Americas, and who is responsible for the writer's interest in Tertiary Mollusca.

### Olssonella vokesae Petit, n. sp.

Plate 1, figs. 1a, 1b

*Diagnosis*: Protoconch smooth and large in proportion, of 2½ whorls. Aperture and spire equal in length. Whorls moderately convex, with impressed suture. Sculpture consisting of strong rounded axial ribs, numbering ten on the body whorl, crossed by about sixteen evenly spaced spiral cords, which rise over the axials. Spiral cords at the shoulder; intermediate, weaker cords in interspaces in some specimens. Aperture semi-lunate, the outer lip well rounded, lirate within, with about nine lirations. Columellar pillar straight, with two plaits of equal size, the lower one descending. Umbilical chink present.

Dimensions of holotype: height 8.4 mm; diameter 4.6 mm.

Holotype: USNM 646465.

Type locality: TU 562, "Silverdale Beds," Onslow County marl pit, on south side of Webb Creek, near Silverdale, Onslow County, North Carolina.

*Occurrence*: Known only from the type locality.

*Figured specimen*: USNM 646465 (holotype).

*Discussion*: This new species, based on a unique specimen collected by Dr. Emily H. Vokes, appears to be ancestral to *Cancellaria smithii* Dall of the Recent Western Atlantic, as well as other related species in the Tertiary of the southeastern United States and Caribbean, and the Tertiary and Recent of the Panamic-Pacific.

### Charcolleria Olsson, 1942

Type, by original designation: *Cancellaria (Charcolleria) perdiciana* Olsson, 1942, Miocene, Colombia.

### Charcolleria distinguenda Petit, n. sp.

Plate 1, figs. 2a, 2b

*Diagnosis*: Shell fusiform, high-spired, aperture slightly longer than apex. Protoconch smooth, glassy, with about 3½ whorls. Whorls convex, suture impressed, with smooth concave depression at the shoulder. Below the shoulder, on the body whorl, about fourteen strong, evenly spaced spiral cords, a few having intermediate weaker cords. Axial sculpture of rounded ribs, numbering about 20 on the body whorl, in general evenly spaced, but obliterated in places by evident stages of rapid growth. The spiral cords cross the axial ribs forming small nodes at the intersections. Aperture elongate-oval, produced into a short anterior canal, strongly lirate within, with about fourteen lirations. Columella with two folds, the posterior one being larger, and the anterior one descending. Umbilicus chink-like.

Dimensions of holotype: height 20.5 mm; diameter 10.8 mm.

Holotype: USNM 646466.

Type locality: TU 546, Chipola Formation, Ten Mile Creek, about 1½ miles west of Chipola River (NE ¼ Sec. 12, T1N, R10W), Calhoun County, Florida.

*Occurrence*: Known only from the type locality.

*Figured specimen*: USNM 646466 (holotype).

*Discussion*: In generic characters, this species is almost intermediate between *Charcolleria* and *Massyla* H. and A. Adams, 1854 (Type: *Cancellaria corrugata* Hinds, Recent, Panamic-Pacific). In *Massyla* the predominant sculpture is spiral, with little if any axial sculpture, the suture is less impressed, and the shell is not openly umbilicate. Though *C. distinguenda* is not openly umbilicate, a strong umbilical chink is present, and the spire is much more acute than in *Massyla*. *Charcolleria distinguenda* is easily distinguished from *Massyla venusta* (Tuomey and Holmes, 1856), *Massyla propevenusta* (Mansfield, 1930), and other *Massyla* by its acute spire. *C. distinguenda* differs from all

described species in having a chink-like umbilicus instead of a more open umbilicus.

The unique type was collected by Dr. and Mrs. H. E. Vokes, Tulane University, New Orleans, Louisiana. No other species of *Charcolleria* has thus far been reported from the southeastern United States.

AGATRIX Petit, 1967

Type, by original designation: *Trigonostoma agassizii* Dall, 1889, Recent, North Carolina to Gulf of Mexico.

AGATRIX DEROYAE Petit, n. sp.

Plate 1, figs. 3a, 3b

*Diagnosis*: General shape as figured. Protoconch helicoidal, smooth, composed of 2½ whorls. Body whorl large, forming two-thirds of the length, the whorls shouldered. Sculpture consisting of axial riblets (11 on the body whorl), overridden by straplike spiral cords set between wider smooth intervals and enlarging into elongated nodes over the summit of the ribs, there being about 13 spiral cords between the shoulder and the anterior canal. On the shoulder-subsutural area three smaller spiral cords. Axial riblets sinuous and extending from the pillar area to the suture. Aperture semi-ovate, the outer lip thin, in some specimens smooth within and in others with up to 13 lirations well within the aperture, and directly beneath the heaviest axial ribs. The siphonal canal widely rounded, but not produced or forming a fasciole. Three columellar plaits, on an inclined pillar, the anterior one forming a keel bordering the siphonal canal.

Dimensions of holotype: height 15.9 mm; diameter 10.7 mm.

Holotype: American Museum of Natural History no. 154676.

Type locality: 150 meters depth, south of Academy Bay, Isla Santa Cruz, Galápagos Islands.

*Occurrence*: Known only from the Galápagos Islands.

*Figured specimen*: American Museum of Natural History no. 154676 (holotype).

*Discussion*: This genus is represented in the Recent fauna by only two species other than the one under discussion: *A. strongi* (Shasky, 1961) from the Gulf of California, and the type species, *A. agassizii* (Dall, 1889), from the western Atlantic. *Agatrix deroyae* may be easily distinguished from *A. strongi* by its more rounded body whorl and its chalky white to light brown coloration. It is represented in the Neogene of Tehuantepec by *A. zapoteca* (Böse, 1910). The relationship of *Agatrix* to the Eocene *Admetula* Cossmann has yet to be determined. Shell morphology is quite similar, but *Admetula* is characterized by the presence of one or more pronounced varices per whorl.

This species has been named for Mrs. Jacqueline DeRoy, who collected the first specimens to come to the writer's attention. These had been sent to Mr. Anthony D'Attilio, who donated them to the American Museum of Natural History, which in turn made them available for study. Of these specimens, and ones later sent to the writer by Mrs. DeRoy, the holotype and paratype remain in the American Museum of Natural History, N. Y., a paratype has been deposited in the United States Natural Museum, (no. 679537) and paratypes remain in the writer's collection.

Four additional specimens were made available for study from the Allen Hancock Foundation collection, which is on loan to the Los Angeles County Museum of Natural History. These bear catalogue numbers AHF 195-34, AHF 201-34, AHF 170-34, and AHF 147-34. I am indebted to Dr. James H. McLean for making these specimens available for study. In addition to Mrs. DeRoy and Dr. McLean, I am also indebted to many others for lending material and for other favors. Among those are: William K. Emerson and William E. Old, Jr. of the American Museum of Natural History, Myra Keen, of Stanford University, Druid Wilson of the U. S. Geological Survey, and Axel A. Olsson of Coral Gables, Florida. They have all contributed materially to the description of this species, and to other phases of the present study of the Cancellariidae.

CANCELLARIA Lamarck, 1799

Type, by monotypy: *Voluta reticulata* Linné, 1758, Recent, North Carolina to Gulf of Mexico.

CANCELLARIA DARWINI Petit, n. sp.

Plate 1, figs. 4a, 4b, 4c

*Diagnosis*: General shape as figured. Protoconch bulimuloid and rather large, of three smooth, glassy whorls, the last large, convex, the first or apical one very small, the coil slightly inclined to the axis and set off sharply from the sculptured first nepionic whorl. Aperture and spire about equal in length. The last whorl moderately convex, the suture distinct. Sculpture faintly cancellate, consisting of numerous weak axial riblets and very narrow spiral cords,

the spirals rising into sharp nodes over the axials. Thirteen spirals between the suture and the anterior canal. Spiral intervals quite wide and plain. Aperture semilunate, the outer lip rounded, inclined, deeply lirate within, with about eight lirations. Columellar pillar straight, with three plaits, the upper strongest. Aperture white; surface color yellowish white, the spiral cords brown.

Dimensions of holotype: Height 18.7 mm; diameter 10.3 mm.

Holotype: American Museum of Natural History no. 154677.

Type locality: 170–200 meters depth, south of Academy Bay, Isla Santa Cruz, Galápagos Islands.

*Occurrence*: Known only from the Galápagos Islands.

*Figured specimen*: American Museum of Natural History no. 154677 (holotype).

*Discussion*: This species is easily distinguished from all other eastern Pacific Cancellarids by its evenly spaced, brown spiral ridges on the cream colored surface. This is a curious species, sculptured and colored much like a *Littorina.* The narrow spiral cords contrast sharply with the background color of the shell. *Cancellaria darwini* is nearest to *C. decussata* Sowerby and *C. gemmulata* Sowerby, but cannot be confused with either due to the aforementioned unique coloration. It is doubtful that this species will remain in *Cancellaria* s.s. when the family is better understood.

All known specimens of *C. darwini* were dredged by Mrs. Jacqueline DeRoy, Isla Santa Cruz, Galápagos Islands. Paratypes have been deposited in the Stanford University collection and in the U. S. National Museum. Other paratypes remain in the Petit collection.

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The following two names are preoccupied. Therefore, new names are here proposed.

ZEADMETE WATSONI Petit, *nom. nov.*

*Cancellaria (Admete) carinata* Watson, 1882, Jour. Linn. Soc. London, v. 16, p. 327.
Not *Cancellaria carinata* Briart and Cornet, 1880. Mém. Acad. Roy. Sci., Lettres, Beaux Arts. Belg., v. 43, p. 14, pl. 14.

This Magellanic species was figured by Watson (1886, pl. 18, fig. 9). The type locality is Royal Sound, 28 fathoms, Kerguelen Island. It has since been reported from the Falklands and Tierra del Fuego at depths of 95–210 meters (Carcelles, 1950, p. 64; Carcelles and Williamson, 1951, p. 304).

Type: BM(NH) 1887.2.9.943.

CANCELLARIA AFRICANA Petit, *nom. nov.*

*Cancellaria imbricata* Watson, 1882, Jour. Linn. Soc. London, v. 16, p. 325.
Not *Cancellaria imbricata* Hörnes, 1856, Die Fossilen Mollusken des Tertiaer-Beckens von Wien, v. 1, Univalves, p. 327, pl. 35, fig. 16.

This species was taken from *Challenger* Station 142, 150 fathoms, off the Cape of Good Hope. It was figured by Watson (1886, pl. 18, fig. 10). There is no question about this species being a cancellarid, but it cannot be placed in *Cancellaria* s.s. Until more

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PLATE 1

Figures Page

1. *Olssonella vokesae* Petit, n. sp. (×6) ..... 84
   USNM 646465 (holotype); height 8.4 mm, diameter 4.6 mm.
   Locality: TU 562. "Silverdale Beds," North Carolina; lower Miocene.
2. *Charcolleria distinguenda* Petit, n. sp. (×3) ..... 84
   USNM 646466 (holotype); height 20.5 mm, diameter 10.8 mm.
   Locality: TU 546. Chipola Formation, Florida; lower Miocene.
3. *Agatrix deroyae* Petit, n. sp. (×3) ..... 85
   AMNH 154676 (holotype); height 15.9 mm, diameter 10.7 mm.
   Locality: Isla Santa Cruz, Galápagos Islands, 150 meters.
4. *Cancellaria darwini* Petit, n. sp. (×3) ..... 85
   AMNH 154677 (holotype); height 18.7 mm, diameter 10.3 mm.
   Locality: Isla Santa Cruz, Galápagos Islands, 170–200 meters.

(In all figures except 4c the specimen is whitened to show details of ornamentation.)

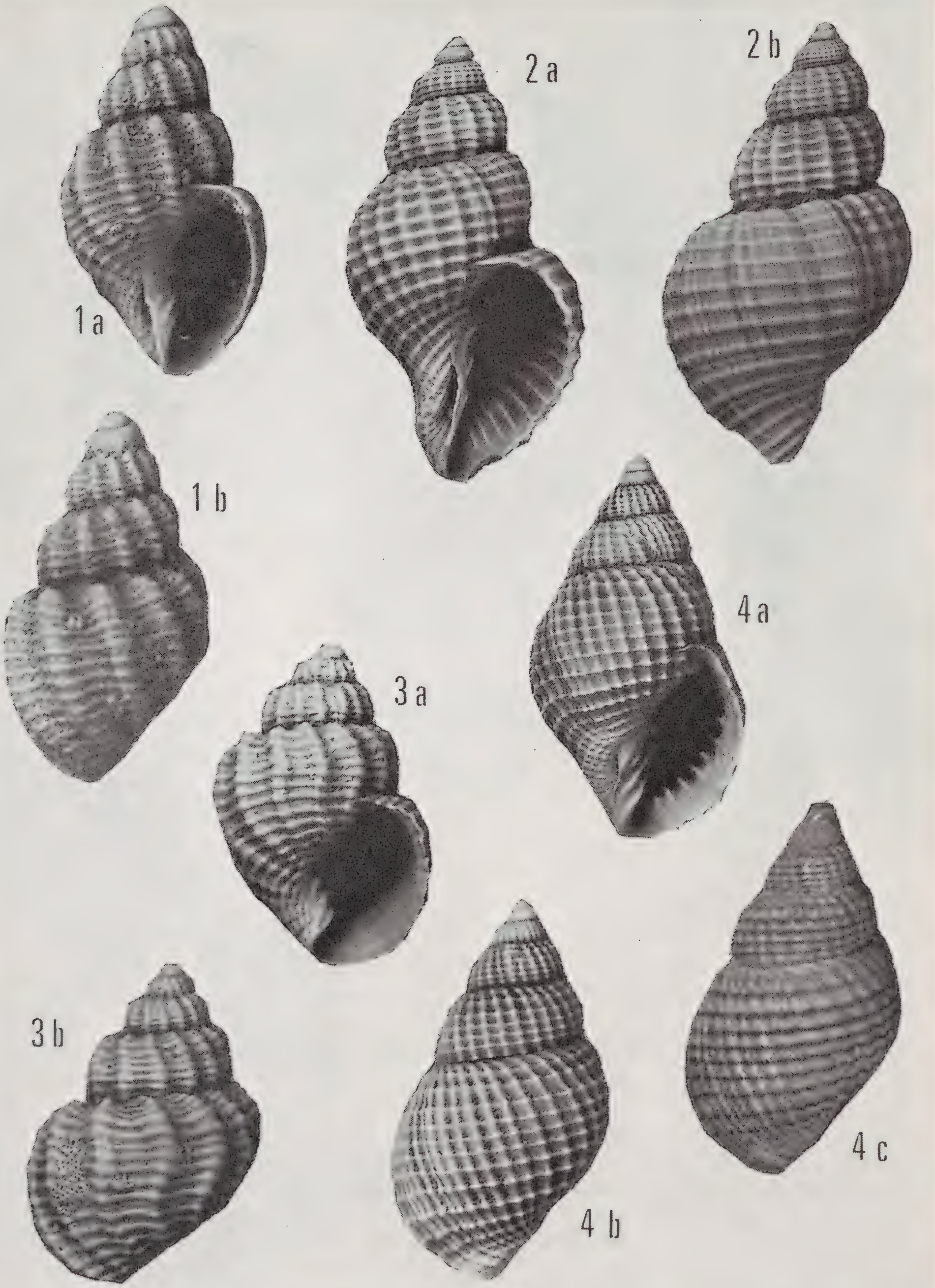


PLATE 1

is known about the relationships within this family, it cannot with certainty be placed in any named genus. Barnard (1958, p. 13) stated that "although Watson said the aspect of the shell suggested an *Admete*, the presence of a radula shows that he placed the species in the correct genus." The presence of a radula, as the family is presently understood, serves only to separate *Cancellaria* from *Admete*, and does not offer, *per se*, any assistance in placement within the complex of *Cancellaria* s.1.

Type: BM(NH) 1887.2.2.940.

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June 17, 1970

# NOTES ON THE FAUNA OF THE CHIPOLA FORMATION—III TWO NEW SPECIES OF *VASUM* (MOLLUSCA: GASTROPODA), WITH COMMENTS ON *VASUM HAITENSE* (SOWERBY)

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When the writer (Vokes, 1966) published a monograph on the genus *Vasum* in the western Atlantic there were two species of *Vasum* known from the Chipola Formation of northwestern Florida. Since then, additional collecting has revealed two new species in this formation, plus many more and better examples of one of the previously described forms, *Vasum haitense* (Sowerby). The second described form, *V. chipolense* Vokes, remains a mystery, with no new material being discovered in spite of extensive additional collecting. Since 1966, collections from 26 new Chipola localities have been added, plus much more material from previous localities. Ironically, the two new species are from one of the oldest known Chipola sites, the "One mile west of Bailey's Ferry, on Ten Mile Creek" (USGS 2212) of Dall and Gardner. One of the most fascinating aspects of the Chipola fauna is its incredible variety. Every collecting trip adds a number of new species and this particular place is one of the richest and most exciting of all of the pres-

Text figure 1. *Vasum haitense* (Sowerby) ( × 1); USNM 646454; height 111 mm, diameter 97.2 mm. Locality: TU 458.

ently known Chipola localities, which number 48 at this writing.

An unresolved problem in the *Vasum* monograph was whether the Tampa Limestone specimen figured by Dall (1915, pl. 11, figs. 2, 3) was of the same species as specimens from the Chipola, named *V. engonatum* by Dall, but synonymized with *V. haitense* by Vokes (1966, p. 10). This specimen was refigured (Vokes, *loc. cit.*, pl. 4, fig. 3) and it was concluded that until better material was discovered it was best not to separate the two forms. No new material has been found of the Tampa species but several very large Chipola specimens are now available, which seem to indicate conclusively that the two are not the same. Prior to this report the largest known specimen of *V. haitense* from Florida was Dall's type specimen for *V. engonatum*, measuring 95 mm in height. In the Tulane collections there are now four large specimens: the one here figured (text fig. 1) from TU 458 is 111 mm; a second from TU 458 is 95 mm; a third from TU 950 is 98 mm; and a fourth from TU 806 is approximately 100 mm (canal broken). These four specimens are all comparable in size to the Tampa specimen, which measures 109 mm in height, and they are consistently different from it. In the Tampa specimen the spines on the spire are separate and distinct from the suture, giving a "Christmas Tree" appearance to the upper part of the shell. In all of the adult Chipola specimens seen, some 30 in number from 14

localities, the spines are enveloped by the succeeding whorl forming a zig-zag suture and giving the spire a very flattened appearance. It is thus concluded that the Tampa specimen is not *V. haitense* but is a new species; however, until a better type specimen is discovered for the Tampa species this writer will not name it.

Quality of the type specimens is not a problem with the two new Chipola species. In spite of the rarity of the two forms the holotypes are so well preserved that there is no doubt about their identification as new taxa.

### VASUM TRIBULOSUM E. H. Vokes, n. sp.

Plate 1, figs. 1a, 1b

*Description*: Shell sub-triangular in outline, eight post-nuclear whorls in holotype, nuclear whorls unknown. Spire angle steep on early whorls, becoming flatter with later whorls. Axial ornamentation of about nine small nodes on early whorls developing sharp pointed spines on median and later whorls. Entire shell corrugated by growth lines. Spiral ornamentation on early whorls of five beaded threads on the shoulder, between the suture and the extended spines at the periphery; these threads are bunched together between the spines and flared out in the area adjacent to the spine, giving an odd "puckered" appearance to the subsutural spirals. On the body whorl an additional eight to ten scabrous major spiral cords and eight to ten minor threads, alternating in size; the two on the anterior canal larger and bearing stubby spines, which correspond to the shoulder spines. Suture appressed but with a small channel on the body portion of the shell; spines projecting over the immediately adjacent suture, causing the suture line to be undulated by their presence. Aperture elongated, flaring at the posterior end. Outer lip polished and slightly crenulated into the major and minor spirals; columellar wall with a moderately heavy callus, bearing three plications, of which the posteriormost is the widest, the anteriormost the narrowest; a space between the two posterior plications suggesting the location of an intermediate smaller plait but it is not developed. Anterior canal straight with a large umbilicus.

Dimensions of holotype: height 87 mm, diameter 62 mm.

Holotype: USNM 646452.

Type locality: TU 546, Ten Mile Creek, north bank, about 1½ miles west of Chipola River (NE ¼ Sec. 12, T1N, R10W), Calhoun County, Florida.

*Occurrence*: Chipola Formation, Florida; (?) late lower Miocene.

*Figured specimen*: USNM 646452 (holotype).

*Discussion*: This new species is based on two beautifully preserved specimens from the classic locality "one mile west of Bailey's Ferry" (USGS 2212). Correctly, it is approximately one and three-quarters miles northwest of "Bailey's Ferry," as it is almost exactly on the quarter-section line between the northeast and northwest quarter sections of Sec. 12, while "Bailey's Ferry" was at the mouth of Ten Mile Creek, in the northwest quarter of Sec. 17, T1N, R9W.

*V. tribulosum* is clearly ancestral to the *V. muricatum* line, differing primarily in the stronger, more scabrous nature of the spiral ornamentation. There are only three columellar plications in *V. tribulosum* but it is obvious that they will give rise to the five of the younger species. There is a space between the two posterior folds that will accommodate the smaller intercalary fold and a suggestion of an anterior fold that will become the strong anteriormost fold seen in *V. muricatum*.

This new species is probably also ancestral to the *Hystrivasum* line as it markedly resembles some members of the group, especially juveniles of *V. jacksonense*, from the upper Miocene Jackson Bluff Formation (= Choctawhatchee Formation, in part). However, it lacks the doubled row of spines that separates the subgenus *Hystrivasum* from *Vasum* s.s.

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PLATE 1

Figures Page

1. *Vasum tribulosum* E. H. Vokes, n. sp. (×1) ..... 90
   USNM 646452 (holotype); height 87 mm, diameter 62 mm.
   Locality: TU 546. Chipola Fm., (?) lower Miocene.
2. *Vasum elongatum* E. H. Vokes, n. sp. (×2) ..... 92
   USNM 646453 (holotype); height 42 mm, diameter 21.5 mm.
   Locality: TU 546. Chipola Fm., (?) lower Miocene.

PLATE 1

## VASUM ELONGATUM E. H. Vokes, n. sp.

Plate 1, figs. 2a, 2b

*Description*: Shell biconic, eight post-nuclear whorls in adult; nucleus of one and one-half smooth, polished, slightly bulbous whorls. Spire angle steep, approximately 60°, remaining constant for the entire development of the shell. Axial ornamentation beginning gradually with six or seven small nodes, which increase in size but do not change in number up to the adult shell. On the median whorls a small open spine is formed at the shoulder on each node, but these become obsolete on the body whorl of the adult. Numerous fine axial growth lines. Spiral ornamentation on early whorls of two major cords, with two smaller threads between the posterior cord and the suture; smaller intercalary threads added subsequently. On body whorl ten major cords and ten alternating smaller threads, varying in strength, some almost as large as the major cords. The major spiral cord circling the anterior canal bearing small rudimentary spinelets, which correspond to the shoulder spines. Suture markedly appressed; a raised ridge following the suture line, which is sinuated by the axial nodes. Aperture pear-shaped, rounded at the posterior end and elongated into the anterior canal. Outer lip bearing about eight long ridges, corresponding to the area between the external major spirals, outer edge of lip crenulated by the major and minor spirals. Columellar lip bearing a heavy callus, with three equi-sized plications. Anterior canal long, straight, with only a small umbilicus.

Dimensions of holotype: height 42 mm, diameter 21.5 mm.

Holotype: USNM 646453.

Type locality: TU 546, Ten Mile Creek, north bank, about 1½ miles west of Chipola River (NE ¼ Sec. 12, T1N, R10W), Calhoun County, Florida.

*Occurrence*: Chipola Formation, Florida; (?) late lower Miocene.

*Figured specimen*: USNM 646453 (holotype). Other occurrences: TU locality nos. 547, 830.

*Discussion*: *V. elongatum* is based on five specimens, two from the type locality, one from another Ten Mile Creek locality, and two from a third locality on the Chipola River. The holotype is the best preserved of the type lot, but it is not adult; one paratype measures 54 mm in height. The holotype does not have a complete aperture so that the description is taken in part from paratype material.

This new species is of the *V. capitellum* line and is most closely related to *V. gurabicum* Maury, from the Gurabo Formation of Santo Domingo. It differs from both of these species in lacking the four heavier spiral ribs with their long spines. The ornamentation of *V. elongatum* is very subdued in its overall aspect, the shell bearing a strong resemblance to a *Polygona* such as *Latirus* (*Polygona*) *maxwelli* or *L.* (*P.*) *mcgintyi*, both of Pilsbry. However, the differences in the columellar plaits and the umbilicus indicate that this resemblance is coincidental.

## LOCALITY DATA

458. Chipola Fm., east bank of Chipola River, above Farley Creek (SW ¼ Sec. 20, T1N, R9W), Calhoun Co., Florida.
546. Chipola Fm., Ten Mile Creek, about 1½ miles west of Chipola River (NE ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.
547. Chipola Fm., west bank of Chipola River, about 2000 ft. above Four Mile Creek (SW ¼ Sec. 29, T1N, R9W), Calhoun Co., Florida.
806. Chipola Fm., west bank of Chipola River, about one mile below powerline crossing (NW ¼ Sec. 20, T1N, R10W), Calhoun Co., Florida.
830. Chipola Fm., Ten Mile Creek, at power line crossing about one mile west of Chipola River (SE ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.

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# NOTES ON MIOCENE BRYOZOA FROM NORTHWESTERN FLORIDA

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## I. Abstract

Three species of cheilostome Bryozoa from two Miocene formations in northwestern Florida are described herein. *Discoporella umbellata depressa* (Conrad) and *Hippoporidra calcarea* (Smitt) are reported for the first time from the Red Bay Formation. The occurrence of *D. umbellata depressa* and *Cupuladria biporosa* Canu and Bassler represent the first report of Bryozoa from the Yellow River Formation. As these species are broad ecologic indicators, it is thought that the Red Bay and Yellow River formations were deposited in muddy, somewhat turbulent, warm temperate environments and under conditions adverse to the development of a large bryozoan community.

## II. Introduction

The present report represents a portion of a larger study undertaken during 1964 as partial fulfillment of the requirements for the degree of Master of Science from the University of Florida. This study has been revised and additional material included during the author's tenure as a Postdoctoral Fellow at the University of Georgia.

The sparse bryozoan fauna of the Red Bay and Yellow River formations of northwestern Florida are discussed herein. Collections of the Red Bay fauna were taken: (1) from a spring head on W. D. McDaniel's farm, Red Bay, Walton County, Florida, 900 feet west of center of Sec. 19, T2N, R17W and (2) from a gully in a field on the east side of Florida Highway 81 across from the Red Bay Fire Tower, NE ¼, SW ¼, NW ¼, Sec. 15, T2N, R17W. The Yellow River fauna is represented by a single collection from a spring head on the C. H. Spence farm, Walton County, Florida, NE ¼, NE ¼, Sec. 17, T2N, R9W. All material was washed through sieves to insure that fragments of both encrusting and erect forms would be salvaged.

Synonymies of the species discussed herein are abbreviated; only the original citation and those references pertaining to fossil or Recent reports in the Gulf of Mexico and/or Caribbean region are given. The figured specimens have been deposited in the U. S. National Museum.

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## III. Stratigraphic Setting

The stratigraphic nomenclature of the upper Miocene units in northwestern Florida has undergone considerable revision in recent years.

The *Arca* faunizone was named by Mansfield (*in* Cooke and Mossom, 1929: 140-142) for sediments exposed in the vicinity of Red Bay, Walton County, Florida, which had been originally designated in 1909 as the type locality of the Choctawhatchee Formation by Matson and Clapp. The *Yoldia* faunizone was proposed by Mansfield and Ponton (1932: 86) for sediments exposed at A. H. Cosson's farm, Walton County, Florida. They believed that these sediments represented the basal beds of the Choctawhatchee Formation.

Puri (1954: 27-28) changed the Choctawhatchee from formational to stage rank and the *Arca* and *Yoldia* faunizones together with the *Ecphora* and *Cancellaria* faunizones were considered facies subdivisions. Puri and Vernon (1964: 115) later revised this nomenclature in part by suggesting the names Red Bay Formation and Yellow River Formation for the *Arca* and *Yoldia* faunizones respectively. As this study is not intended to re-examine critically the stratigraphic nomenclature of this area, the suggestion by Puri and Vernon to use the names Red Bay and Yellow River formations is followed.

## IV. Paleoecology

Bryozoa have been known to occur in the Red Bay Formation, but previously they have not been reported from the Yellow River Formation. Lagaaij (1963: 199, text-fig. 19) indicates the presence of *Cupuladria biporosa* Canu and Bassler [reported as *C. canariensis* (Busk)] in the Red Bay Formation. Lagaaij's material also comes from the type locality at McDaniel's farm. The Red Bay fauna is known to consist of *Cupuladria biporosa*, *Discoporella umbellata depressa* (Conrad), and *Hippoporidra calcarea* (Smitt); *D. umbellata depressa* and *C. biporosa* are reported for the first time from the Yellow River Formation. The paleoecology of both formations has been interpreted through the use of ecologic indicators among the mollusks, foraminifers, and ostracods. Although the number of bryozoan species is small, those present are ecologic indicators and provide broad information to supplement the present knowledge about both formations.

### *Red Bay Formation*

Lagaaij (1963: 187-190), summarizing his studies on *Cupuladria canariensis* (sensu lato), noted that there is a definitive relationship between maximum depth and minimum temperature. The minimum temperature for survival appears to be about 12° C because this species has been found at variable depths in which the temperature is no colder than 12° C. Similarly, the maximum temperature is thought to be approximately 31°-32° C and to control the upper depth limit, ranging as shallow as five fathoms. The temperature tolerance of these species controls their geographic distribution, limiting them to waters between the 14° C surface isocrymes in the northern and southern hemispheres. Cook (1965b: 209) observed that *C. canariensis* and *C. biporosa* "have similar geographical distributions, live in similar depths, under the same ecologic conditions, and are thus frequently associated in Recent collections."

*Cupuladria biporosa* is an abundant form in the Red Bay Formation and, therefore, it is likely that its survival and reproduction rates were high. The paleotemperatures indicated by the occurrence of this species, 12°-14° C to 31°-32° C, are similar to temperatures recorded in the adjacent part of the Gulf of Mexico today.

The small number of species in the Red Bay fauna may be attributable to a high rate of deposition and/or a soft, fine-grained substrate. Lagaaij (1963: 174) observed that the deposition of clay particles between 5 and 50 fathoms near the mouth of the Mississippi River limited the bryozoan types largely to lunulitiform Bryozoa.

At the type locality, at least 35 feet of sediments attributable to the Red Bay Formation are exposed. Puri (1954: 30-31) reported a minimum of 41 feet of Red Bay sediments in an auger hole drilled in the vicinity of the Red Bay Fire Tower. His interpretation of well sections in Okaloosa County indicates that the formation thickens downdip to about 230 feet. Exposures of the formation have been recorded in northeastern Walton County, western Washington County, and southwest-

ern Holmes County. The total amount of sediment deposition was considerable, but the samples examined were collected from the updip segment of the formation, where the amount was not as great.

The second possible explanation for the small number of species is the lack of firm substrate. The majority of bryozoans require a stable substrate for attachment and subsequent growth. Large inorganic particles were not observed in the Red Bay Formation; the bulk of the sediments are fine-grained (clay- to silt-sized) marls intermixed with quartz sands. Living space for sessile organisms is limited to mollusk shells. Much of this material was not accessible in the paleoenvironment as many of the molluscan species were burrowing forms. Although shell fragments and non-burrowing mollusks are common, only a single specimen of an encrusting Bryozoa was recovered. The small particle size indicates a general lack of sediment "winnowing." Hence, suitable substrate material on the surface of the bottom would have been covered rapidly by fine-grained sediments, ultimately resulting in a depauperate encrusting epifauna.

The small bryozoan community probably is the result of both factors. Appreciable sedimentation in combination with a soft, muddy bottom having a paucity of suitable substrate for sessile organisms would have an inhibitive effect on the development of a bryozoan community.

### *Yellow River Formation*

Two species reported herein occur only sparsely in the formation. Seventeen fragments of *Discoporella umbellata depressa* and one fragment of *Cupuladria biporosa* have been recovered from over 400 cc of sieved sediments.

The molluscan genus *Yoldia* occurs commonly in Recent cold water seas and is a dominant element in the Yellow River Formation. Thus Mansfield and Ponton (1932: 86) suggested that the Yellow River Formation possibly represented cold water deposits. This suggestion is doubtful inasmuch as *Yoldia solenoides* Dall, a Recent congener, occurs in the offshore muddy bottoms in the present day northern Gulf of Mexico.

*Discoporella umbellata depressa*, *Cupuladria biporosa* and *C. canariensis* occupy nearly the same ecologic niche. The presence of the first two species in the formation precludes a truly cold water paleoenvironment. It seems evident from Puri (1954) and Puri and Vernon (1964) that the Red Bay and Yellow River are more or less contemporaneous and that one is a facies of the other. Therefore, paleotemperatures in the Yellow River Formation probably would not differ significantly from those occurring in the paleoenvironment of the Red Bay Formation.

The absence of encrusting Bryozoa in the Yellow River Formation suggests adverse ecologic conditions for their development. The sediments of the formation are composed of sandy clays and marls with a sparse micro- and macrofauna and thus nearly devoid of suitable substrate for sessile organisms. Sand-sized particles are abundant, and all inhibiting factors excluded, lunulitiform Bryozoa should be abundant. However, this is not the case in the Yellow River Formation as only 17 small fragments of *Discoporella* were recovered.

The formation is exposed only at the type locality and at C. H. Spence's farm. Puri (1954: 29) reported at least 75 feet of Yellow River sediments from an auger hole drilled at the type locality. In view of the thickness of the sediments, the rate of sedimentation probably was appreciable. It is suggested that the absence of encrusting and the paucity of lunulitiform Bryozoa is related to the amount of particle deposition in the formation.

## V. Systematic Paleontology

### Order Cheilostomata Busk

### Suborder Anasca Levinsen

### Family Cupuladriidae Lagaaij

### Genus Cupuladria Canu and Bassler

*Cupuladria* Canu and Bassler, 1919, Carnegie Inst. Washington, Publ. no. 291, p. 77.

Type species: *Cupularia canariensis* Busk, 1859, Quart. Jour. Micros. Sci., v. 7, p. 66, pl. 23, figs. 6, 9 [*non* pl. 23, figs. 7, 8 = *C. biporosa* Canu and Bassler] (by original designation). Recent, Madeira and Canary Islands.

### Cupuladria biporosa Canu and Bassler

Text-fig. 1

*Membranipora canariensis* (Busk). Smitt, 1873, Kongl. Svenska Vetensk.-Akad. Handl., v. 11, pt. 4, p. 10, pl. 2, figs. 69-71.

*Cupuladria canariensis* (Busk). Canu and Bassler, 1919, Carnegie Inst. Washington, Publ. no. 291, p. 78, pl. 1, figs. 8-10; Canu and Bassler, 1920, U. S. Natl. Mus., Bull. 106, p. 103, text-fig. 24D; Canu and Bassler, 1923, U. S. Natl. Mus., Bull. 125, p. 28, pl. 1, figs. 7-9; Canu and Bassler, 1928, U. S. Natl. Mus., Proc., v. 72, art. 14, p. 15, text-fig. 2; McGuirt, 1941, Louisiana Geol. Survey, Bull. 21, p. 46, pl. 1, figs. 1-3, 5, 6, 8.

*Cupuladria biporosa* Canu and Bassler, 1923, U. S. Natl. Mus., Bull. 125, p. 29, pl. 47, figs. 1, 2.

*Cupuladria biporosa* Canu and Bassler. Cook, 1965, Bull. Brit. Mus. (Nat. Hist.), Zool., v. 13, no. 6, p. 203, pl. 1, figs. 2A, B, 3A, B, 4A, B, 5, 6A, B, text-figs. Ig-j.

*Cupuladria* sp. Cheetham and Sandberg, 1964, Jour. Paleontology, v. 38, no. 6, p. 1021.

*Description*: Zoarium discoidal or saucer shaped, generally free in adult stage, Zooecia rhomboidal, closely packed, arranged in quincunx. Gymnocyst lacking; cryptocyst granular, generally narrow but may be moderately wide, widest proximally, narrowing laterally, descending sharply, and nearly lacking distally. Opesia rhomboid in shape, almost extending the entire length in frontal view. Zooecial walls vertical or sloping, obscured laterally and proximally by the cryptocyst; distally, where cryptocyst thinest, wall readily apparent, sloping downward. An auriform vibraculum distal to each zooecium; occasionally a much larger vibraculum found in the position of a normal zooecium. Basal surface divided into sectors, each bearing two to six pores.

*Material examined*: USNM 651283, figured specimen, Red Bay Formation, Red Bay Fire Tower, Florida. USNM 651284, specimen not figured, Yellow River Formation, C. H. Spence Farm, Florida.

*Fossil distribution*: Miocene: Anahuac and Upper Frio formations, Texas; Catahoula Formation, Louisiana; Chickasawhay Formation, Mississippi and Alabama; Shoal River, Chipola, Red Bay, Yellow River, and Jackson Bluff formations, Florida; Bowden Formation, Jamaica; Cercado Formation, Dominican Republic; Gatun Formation, Costa Rica. Pliocene: Caloosahatchee Formation, Florida; Minnitimmi Creek, Bocas Island, Panama.

*Remarks*: Cook (1965b: 203, 209) has summarized succinctly the morphologic distinctions between *C. canariensis* and *C. biporosa*. Cook (p. 207) noted from McGuirt's published figure (1941: pl. 1, fig. 8) that the cryptocyst appeared to be unusually narrow and may have been worn. The Red Bay specimens also have a number of zooecia that bear a narrow cryptocyst, although in this case no wear is evident.

Text-figure 1. *Cupuladria biporosa* Canu and Bassler, USNM 651283, frontal view showing vicarious vibraculum in lower left, × 50.

A single, badly worn fragment was found in the sievings from the Yellow River Formation. The frontal surface has been abraided away and identification was made on the basis of the characteristic porous basal surface.

## Genus Discoporella d'Orbigny

*Discoporella* D'Orbigny, 1852, Paléontologie francaise, terrains crétacés, v. 5, p. 472.

Type species: *Lunulites umbellata* Defrance, 1823, Dictionnaire des sciences naturelles, v. 27, p. 361, pl. 47, figs. 1, 1a, b (subsequent designation by Hastings, 1930). Miocene, France.

### Discoporella umbellata depressa (Conrad)

Text-fig. 2

*Lunulites depressa* Conrad, 1841, Amer. Jour. Sci., ser. 1, v. 41, p. 348.

*Discoporella denticulata* (Conrad). Gabb and Horn, 1862, Jour. Acad. Nat. Sci. Philadelphia, ser. 2, v. 5, p. 142, pl. 20, fig. 25.
*Cupularia umbellata* (Defrance). Smitt, 1873, Kongl. Svenska Vetensk.-Akad. Handl., v. 11, pt. 4, p. 14, pl. 3, figs. 75-80; Canu and Bassler, 1919, Carnegie Inst. Washington, Publ. no. 291, p. 85, pl. 1, figs. 5-7, pl. 2, figs. 17-21; Canu and Bassler, 1923, U. S. Natl. Mus., Bull. 125, p. 80, pl. 2, figs. 15-19, text-fig. 10G; Canu and Bassler, 1928, U. S. Natl. Mus., Proc., v. 72, art. 14, p. 64, pl. 7, figs. 1-3.
*Cupularia lowei* Busk. Osburn, 1914, Carnegie Inst. Washington, Publ. no. 182, p. 194.
*Cupularia robertsoniae* Canu and Bassler, 1923, U. S. Natl. Mus., Bull. 125, p. 82, pl. 34, figs. 5-7.
*Discoporella umbellata* (Defrance). McGuirt, 1941, Louisiana Geol. Survey, Bull. 21, p. 65, pl. 1, figs. 4, 7, 9-11.
*Discoporella umbellata depressa* (Conrad). Cook, 1965, Bull. Brit. Mus. (Nat. Hist.), Zool., v. 13, no. 5, p. 180, pl. 3, figs. 2, 4.

*Description*: Zoarium discoidal to saucer-shaped, generally free in adult stage. Zooecia rhomboid, somewhat regularly arranged. Gymnocyst absent; finely tuberculated proximal and lateral cryptocyst descends gently to a horizontal cryptocyst that bears 8-12 peripheral pores and frequently, scattered central pores; development of horizontal cryptocyst may vary from delicate lacework to a complete lamina with peripheral openings. Opesia small, nearly semicircular, the proximal border curved. Auriform vibraculum distal to each zooecium. Basal surface bears closely spaced coarse tubercles and divided into radial sectors by short discontinuous grooves.

*Material examined*: USNM 651285, figured specimen, Red Bay Formation, Red Bay Fire Tower, Florida. USNM 651286, specimen not figured, Yellow River Formation, C. H. Spence Farm, Florida.

*Fossil distribution*: Miocene: Shoal River, Chipola, Oak Grove, Red Bay, Yellow River, and Jackson Bluff formations, Florida; Bowden Formation, Jamaica; Cercado Formation, Dominican Republic; Duplin Marl, North and South Carolina; subsurface of Louisiana. Pliocene: South Carolina and Florida. Pleistocene: California.

## Suborder Ascophora Levinsen

## Family Cleidochasmatidae

## Cheetham and Sandberg

## Genus Hippoporidra Canu and Bassler

*Hippoporidra* Canu and Bassler, 1927, U. S. Natl. Mus., Proc., v. 69, art. 14, p. 8.
Type species: *Cellepora edax* Busk, 1859, Palaeontogr. Soc. Mon. (1857), p. 59, pl. 9, fig. 6; pl. 22, fig. 3 (by original designation). Pliocene, England.

Text-figure 2. *Discoporella umbellata depressa* (Conrad), USNM 651285, frontal view, × 50.

### Hippoporidra calcarea (Smitt)

*Lepralia edax* forma *calcarea* Smitt, 1873, Kongl. Svenska Vetensk.-Akad. Handl., v. 11, pt. 4, p. 63, pl. 11, figs. 220-223.
*Hippoporidra janthina* (Smitt). Cheetham and Sandberg, 1964, Jour. Paleontology, v. 38, no. 6, p. 1033, text-fig. 36.

*Description*: Zoarium encrusting, often forming distinct irregular erect branches. Zooecia irregularly oriented, shape varying with degree of zooecial crowding. Frontal generally thickened, bearing one to two rows of marginal pores. Orifice nearly semicircular, bearing prominent, proximally placed condyles; proximal lip broadly curved. Medial suboral umbo commonly present.

*Material examined*: USNM 651287, specimen not figured, Red Bay Formation, Red Bay Fire Tower, Florida.

*Fossil distribution*: Miocene: Red Bay Formation, Florida. Quaternary: subsurface of Louisiana.

*Remarks*: A single small specimen was recovered in the collections taken from the site near the Red Bay Fire Tower. The significance of this occurrence is not clear at this time.

The heavily calcified specimen appears to lack avicularia and no ovicells are present.

The following supplementary description is from Cheetham and Sandberg (1964: 1033): "avicularia small, pointed, frontal, having cross bars, locally on umbonate process; ovicells globular, coarsely granular, displaying large area of secondary calcification."

## VI. Acknowledgments

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and

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NEW TERTIARY CALCAREOUS NANNOFOSSILS

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*U. S. GEOLOGICAL SURVEY, LA JOLLA, CALIFORNIA*

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# CALCAREOUS NANNOFOSSILS FROM THE *JOIDES* BLAKE PLATEAU CORES, AND REVISION OF PALEOGENE NANNOFOSSIL ZONATION

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## ABSTRACT

The calcareous nannofossil zonation for the Paleocene-Eocene interval has been refined by study of samples previously dated with planktonic foraminifers and of samples from continuous sections. In the middle Paleocene one additional distinctive zone, the *Cyclococcolithina robusta* Zone, is recognizable. The middle and upper Eocene interval, formerly divided into two zones, the *Discoaster tani nodifer* Zone (≅ *Coronnulus germanicus* Zone) and the *Isthmolithus recurvus* Zone, can be divided into nine zones:

1. the *Discoaster tani* s.l.—*Sphenolithus radians* Zone;
2. the *Reticulofenestra umbilica*—*Sphenolithus furcatolithoides* Zone;
3. the *Pemma papillatum* Zone;
4. the *Bramletteius serraculoides* Zone;
5. the *Helicopontosphaera compacta*—*Chiasmolithus grandis* Zone;
6. the *Hayella situliformis* Zone;
7. the *Isthmolithus recurvus* Zone (emended);
8. the *Sphenolithus predistentus*—*Discoaster barbadiensis* Zone;
9. the *Helicopontosphaera reticulata* Zone.

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The lower Tertiary sediments penetrated in JOIDES Blake Plateau cores J–3, J–4, and J–6B can be zoned effectively with calcareous nannofossils. J–3 contains lower, middle and upper Eocene sediments, but the section is discontinuous and contains numerous gaps. J–4 contains an upper Paleocene section from the *Discoaster gemmeus* Zone through the *Discoaster multiradiatus* Zone. J–6B contains a discontinuous record of lower and middle Eocene sediments and a continuous upper Eocene section, from the *Hayella situliformis* Zone on up. The Eocene-Oligocene boundary is contained in cores J–3 and J–6B, but because of the inadequacy of the definition of this boundary in terms of biostratigraphic criteria, its exact level remains undetermined.

## I. Introduction

In April and May of 1965 the drilling ship MV *Caldrill* I, under the auspices of JOIDES and the sponsorship of the National Science Foundation, drilled six sites off the east coast of Florida, east and southeast of Jacksonville. Two of the sites (nos. 1 & 2) are on the continental shelf, and one site (no. 5) is on the continental slope. The remaining three sites are on Blake Plateau, a broad platform bounded to the west by the foot of the continental slope, and to the east by a steep escarpment which drops off to the ocean basin. At sites 3, 4 and 6 a more or less complete Tertiary section was penetrated down to the upper Paleocene. Because of operational difficulties, however, not all of the section was recovered in the cores.

The sediments consist largely of calcareous pelagic ooze, except that in the Eocene interval significant amounts of chert were encountered, interbedded with the calcareous sediments. The calcareous sediments are made up chiefly of the skeletal remains of planktonic organisms—coccolithophores and planktonic foraminifers—along with some minor amounts of fine detrital constituents. A preliminary report of the drilling operation and of the sediments recovered was published by JOIDES in *Science*, **150**,(3697): 709–716, 1965. A cruise report and preliminary core log were prepared on behalf of the JOIDES Blake Panel by John Schlee and Robert Gerard. The latter report is unpublished.

Calcareous nannofossils have proven particularly useful for dating of calcareous deep sea sediments, of which they commonly constitute a considerable fraction. This has been demonstrated with numerous samples recovered with conventional coring equipment in various parts of the world oceans. The JOIDES Blake Plateau cores, however, offer the first opportunity to study nannofossils in substantial sections of Paleogene pelagic sediments from the deep ocean basin.

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## II. Purpose and Scope

The purpose of this study is to identify the calcareous nannofossils—coccoliths, discoasters and associated forms—in the Paleocene-Eocene sediments recovered at JOIDES sites 3, 4 and 6 on Blake Plateau; to determine the stratigraphic distribution of the various taxa within the above interval; to date this interval on the basis of presently available nannofossil zonation; and, finally, to determine what further refinements can be made on the current nannofossil zonation scheme.

## III. Methods and Techniques

Techniques for the preparation of nannofossil samples have been described in numerous publications, as also have been methods of study both with light and electron microscopes. In addition to optical techniques widely used for studying calcareous nannofossils (phase contrast, cross-polarized light, oblique illumination), interference contrast optics were found particularly useful in the examination of certain types of coccoliths with the light microscope. Electron microscope studies were made on single stage carbon replicas with a Phillips 100 transmission type electron microscope.

## IV. Previous Work

The first use of calcareous nannofossils as a means for biostratigraphic correlation of early Tertiary deposits was the study of Bramlette (1957) in which the Eocene and Oligocene deposits of Saipan were correlated on the basis of coccoliths and discoasters. The

first formal nannofossil zones were proposed by Brönnimann and Stradner (1960) for the Paleocene to Oligocene deposits in Cuba, where these authors recognized six distinct discoaster zones for this interval. In 1961 Bramlette and Sullivan presented a nannofossil zonation of the upper Paleocene to middle Eocene deposits of the Lodo Formation of California in which they proposed six biostratigraphic units for this interval. Sullivan (1964, 1965) expanded this work to include other lower Tertiary deposits from various localities in central and southern California. In the process, he compressed the six "biostratigraphic units" into four "faunizones."

Gohrbandt and Stradner proposed a zonation of the Paleocene and basal Eocene of Austria (Gohrbandt, 1963) based on the occurrence of planktonic foraminifers, nummulitids and calcareous nannofossils; and Hay (1964) worked out a zonational scheme for the middle part of the Paleocene to middle Eocene based on the discoasters of the Schlierenflysch of Switzerland. Hay's zones subsequently were correlated with planktonic foraminifer zones, nummulitid zones, alveolinid zones, and the standard European stages for the Paleocene-lower Eocene by Luterbacher and Premoli Silva (1964). Additional information on the distribution of calcareous nannofossils in lower Tertiary sediments was given by Martini (1961), Lezaud (1964), Locker (1965, 1968), Sales (1966), Levin and Joerger (1967), Reinhardt (1967), and Hay, *et al.* (1967). Hay and Mohler (1967) presented a detailed nannofossil zonation of the Paleocene based on a surface section at Pont Labau in SW France. Similarly detailed information has been presented by Radomski (1967, 1968) for the Paleogene calcareous nannoplankton of the western Polish Carpathians, and by Bystrická (1969) for the Paleogene discoasters of the western Carpathians in Slovakia.

## V. Biostratigraphic Zonation

Several detailed and more or less comprehensive nannofossil zonations have been presented for the Paleogene (Hay, *et al.*, 1967; Radomski, 1967, 1968). These schemes essentially are very similar, as they are, in large part, successive expansions of the same zonations. In all of them the data of earlier investigators, especially that of species range relations indicated by Bramlette and Sullivan (1961), are utilized to supplement the new data.

There are, however, differences in the emphasis placed on one species or another as stratigraphic markers. These differences appear to reflect local or regional differences in the composition of the nannofossil assemblages, which in turn were probably caused by differences in the environments prevailing in the various regions. One such difference is noted in the abundance of fossil holococcoliths, which may be common or abundant in certain hemipelagic sediments, but often are completely lacking in age equivalent open ocean pelagic oozes (Gartner and Bukry, 1969). Similarly, various species of pentaliths may constitute a significant portion of the nannofossil assemblage in sediments deposited relatively closer to a continental area, while in the open ocean they are only very sparsely represented (see for example Bukry, 1970). The latter group is represented by a variety of ornate and unusual species in middle and upper Eocene sediments deposited in marginal pelagic environments (Bouché, 1962; Chang, 1969; Bukry and Bramlette, 1969).

The calcareous nannofossil zonation used for this study is a modified version of that devised by Hay and others during the past five years, and which was correlated with the planktonic foraminiferal zonation scheme during the working session of the Colloque sur l'Éocène in Paris in May 1968 (Cita, 1969). The present modification was first presented at the 1969 Eocene Colloquium in Hungary. The planktonic foraminiferal zonation is that of Blow (1969) except for the *Globigerina eugubina* Zone which is not included in Blow's zonation (fig. 1).

The modifications in the nannofossil zonation scheme have been prompted by the recognition of several additional nannofossil datums, one in the middle Paleocene, and several more in the middle and upper Eocene. These have been recognized chiefly through the study of nannofossils from samples which were previously dated by means of planktonic foraminifers. Because these samples were obtained from widely separated geographic localities, and represent different lithologies—in many instances probably reflecting different environments—the zona-

tion scheme may have some inherent weaknesses. As was pointed out above the holococcoliths and pentaliths are most commonly found in hemipelagic sediments. In addition, the Tertiary rhabdoliths commonly constitute a much larger proportion of the assemblage in sediments deposited near a continental area than in truly pelagic sediments. The same generalization appears to be true, although to a lesser extent, for the genus *Helicopontosphaera* and for the species *Isthmolithus recurvus* Deflandre, *Hayella situliformis* Gartner, *Chiasmolithus titus* Gartner, and *Corannulus germanicus* Stradner. The opposite effect is noted for the species *Bramletteius serraculoides* Gartner, which is encountered in large numbers in truly pelagic sediments but is rare or lacking in clayey sediments or sediments deposited under strong continental influences. Most placolith species (*Coccolithus, Cyclococcolithina,* etc.) and asteroliths (*Discoaster*) appear to be more cosmopolitan in their distribution in sediments of the same age.

The reason for these differences in the geographic distribution of various taxa is not entirely clear. It may reflect environmental preferences of the organisms that produced the coccoliths, or possibly, it may be a preservation artifact, *i.e.* some nannofossils are preserved readily in the clayey sediments deposited near continental areas, but commonly dissolve or disintegrate in the open oceanic environment where pelagic oozes accumulate.

These differences in distribution are taken into account in the present zonation, and whenever possible cosmopolitan species are used as zonal indicators. It should be noted that among the nannofossils which appear to be limited in geographic distribution are many distinctive and ornate species but because of their limited environmental range, their biostratigraphic usefulness is similarly limited.

The revisions in the Paleogene nannofossil zonation scheme prepared for the 1969 Eocene Colloquium will be reviewed briefly and updated here.

In the Paleocene the *Cruciplacolithus tenuis* Zone probably can be divided into several distinct subunits, but only one can be properly defined at this time. This is the *Cyclococcolithina robusta* Zone, which is the interval from the earliest occurrence of *Cyclococcolithina robusta* (Bramlette and Sullivan), n. comb. (= *Cyclolithus? robustus* Bramlette and Sullivan, 1961, p. 141, pl. 2, figs. 7 a–c) to the earliest occurrence of *Fasciculithus tympaniformis* Hay and Mohler. The *Cyclococcolithina robusta* Zone is within the upper part of the *Cruciplacolithus tenuis* Zone of Mohler and Hay (Hay, *et al.,* 1967), and in terms of Blow's planktonic foraminifer zones, extends from about the middle of zone P2 to the lower part of zone P3. The earliest occurrence of *Cyclococcolithina robusta* also corresponds approximately to the first occurrence of *Ellipsolithus macellus* (Bramlette and Sullivan), *Toweius craticulus* Hay and Mohler, and *Chiasmolithus bidens* (Bramlette and Sullivan). On figure 1 this is indicated as the *Chiasmolithus bidens* datum.

The remaining revisions concern the middle and upper Eocene interval which previously was divided into two zones, the *Discoaster tani nodifer* Zone (approximately Radomski's *Corannulus germanicus* Zone), roughly equivalent to the middle Eocene, and the *Isthmolithus recurvus* Zone, which is approximately equivalent to the upper Eocene. The base of the *Discoaster tani nodifer* Zone is defined by the earliest occurrence of the nominal species, and above this are several important datums which are indicated in figure 1. The lowest in the sequence is the *Reticulofenestra* datum, marked by the earliest occurrence of *Reticulofenestra umbilica* (Levin). Although the early representatives of this species are smaller than the typical forms encountered in the upper Eocene, the species is cosmopolitan in its distribution, common throughout its range, and hence a good stratigraphic indicator (see also systematic section on *Reticulofenestra umbilica*).

The next higher datum is the earliest occurrence of *Pemma papillatum* Martini, a distinctive pentalith, which, as most pentaliths, is common in marine sediments that show continental influences, but may be very scarce in pelagic ooze of this age. The *Bramletteius* datum succeeds this, marked by the earliest occurrence of *Bramletteius serraculoides.* It is easily recognized in pelagic oozes where it is common to abundant. This same species, however, may be only rarely encountered in hemipelagic sediments.

Next is the *Discoaster saipanensis* datum which corresponds closely to the earliest occurrence of three species: *Discoaster saipanensis* Bramlette and Riedel, *Pedinocyclus larvalis* (Bukry and Bramlette) and *Helicopontosphaera compacta* (Bramlette and Wilcoxon), n. comb. (= *Helicosphaera compacta* Bramlette and Wilcoxon, 1967, p. 105, pl. 6, figs. 5–8). The first occurrence of these three species probably does not coincide exactly, but seems to be fairly close in time.

Above this is the *Helicopontosphaera reticulata* datum, which is marked by the first occurrence of *Helicopontosphaera reticulata* (Bramlette and Wilcoxon), and which corresponds closely to the level of first occurrence of *Hayella situliformis* and *Chiasmolithus oamaruensis* (Deflandre), as well as the last occurrence of *Chiasmolithus grandis* (Bramlette and Riedel). This datum is near the top of the middle Eocene interval, somewhat below the top of the *Truncorotaloides rohri* Zone, and is the uppermost datum recognizable within the middle Eocene. Although each of the above three species is distinctive and easily recognized, this datum may be difficult to determine because in pelagic oozes all three species may be only sparsely represented or lacking entirely.

The next higher datum indicated is marked by the first occurrence of *Isthmolithus recurvus*. At the working session of the Colloque sur l'Éocène in Paris in 1968 (Cita, 1969) this datum was correlated approximately with the middle of the *Globigerapsis semiinvoluta* Zone (= *Globigerapsis mexicana* Zone of Blow's terminology). If this correlation is correct then the range of *Chiasmolithus grandis* may have to be extended into the upper Eocene interval, as this species occasionally may be found together with *Isthmolithus recurvus* (see for example Radomski, 1968, Table 3). The above two species commonly are not found together, nor has there been clearly established an overlapping of the ranges of *Chiasmolithus grandis* and *Chiasmolithus oamaruensis* (Gartner, in press). Nevertheless, it should be pointed out that the *Hayella situliformis* Zone indicated on the chart, may exist only locally or in environments from which *Isthmolithus recurvus* and/or *Chiasmolithus grandis* were excluded.

Next above is the datum marked by the first abundant occurrence of *Sphenolithus predistentus* Bramlette and Wilcoxon and *Sphenolithus pseudoradians* Bramlette and Wilcoxon. This datum also may be difficult to determine at times, because the two species marking it may be encountered sporadically at lower stratigraphic levels. However, all of these occurrences are very rare and contamination cannot be ruled out; additional sections through this interval must be studied before this datum can be fixed.

Finally, the youngest Eocene datum is marked by the last occurrence of *Discoaster barbadiensis* Tan, which also corresponds closely to the last occurrence of *Discoaster saipanensis* and *Cyclococcolithina reticulata* (Gartner and Smith), and to the first occurrence of *Quinquerhabdus colossicus* Bukry and Bramlette. This datum was considered to correspond to the Eocene-Oligocene boundary and is so indicated on the correlation chart compiled by the working session of the 1968 Eocene Colloquium in Paris (Cita, 1969). However, Blow (1969) has included in the planktonic foraminifer zone P17, the *Globigerina gortanii—Globorotalia centralis* Zone, strata which appear to be above the extinction level of *Discoaster barbadiensis*. The upper part of the type Shubuta Clay in Mississippi, traditionally included in the upper Eocene, is assigned by Blow to the foraminiferal zone P17, although *Discoaster barbadiensis* is lacking at the top of this unit. Similarly, *Discoaster barbadiensis* is not present in much of the section in JOIDES core 3 from Blake Plateau which Blow assigns to zone P17; however, Blow's age determination of this interval may require revision. Samples from the Marne di Brendola, from the uppermost Priabonian (upper Eocene) contain *Discoaster barbadiensis* in the interval assigned by Cita to the *Globigerina gortanii* Zone (= zone P17), which does not agree with the scheme proposed by Blow (1969) (see also Proto-Decima, 1969). The exact position of the Eocene-Oligocene boundary with respect to nannofossil datums is left open at this time, at least until some of the present contradictions can be resolved.

The various nannofossil datums listed above can be transformed into a zonation scheme such as is indicated on figure 1. The limits of the zones are indicated by the datums, and the zones are defined as follows:

*Discoaster tani* s.l.—*Sphenolithus radians*

Zone: Interval from the first occurrence of *Discoaster tani* s.l. to the first occurrence of *Reticulofenestra umbilica.* This zone corresponds to the lowermost portion of the *Discoaster tani nodifer* Zone of Hay (1967). *Chiasmolithus titus* first appears near the base of this zone. *Sphenolithus radians* Deflandre was earlier thought to occur no higher than this zone, however this may not be true, as *Sphenolithus radians* has been encountered sporadically in younger middle Eocene sediments.

*Reticulofenestra umbilica—Sphenolithus furcatolithoides* Zone: Interval from the first occurrence of *Reticulofenestra umbilica* to the first occurrence of *Pemma papillatum.* The holococcolith *Lanternithus minutus* Stradner first appears within this zone, and *Sphenolithus furcatolithoides* Locker and *Helicopontosphaera seminulum seminulum* (Bramlette and Sullivan), n. comb. ( = *Helicosphaera seminulum seminulum* Bramlette and Sullivan, 1961, p. 144, pl. 4, figs. 1 a–c, 2) become extinct near the top of this zone.

*Pemma papillatum* Zone: Interval from the first occurrence of *Pemma papillatum* to the first occurrence of *Bramletteius serraculoides.* The holococcolith *Daktylethra punctulata* Gartner apparently is restricted to this zone. Also within this interval occur many varied pentalith species such as have been described by Bouché (1962), Chang (1969), and Bukry and Bramlette (1969). These pentaliths are unusually well developed in the upper part of the Lisbon Formation at Little Stave Creek in Alabama.

*Bramletteius serraculoides* Zone: Interval from the first occurrence of *Bramletteius serraculoides* to the first occurrence of *Helicopontosphaera compacta. Chiasmolithus consuetus* (Bramlette and Sullivan) has its last occurrence within this zone, and *Coccolithus floridanus* Roth and Hay first appears within this zone.

*Helicopontosphaera compacta—Chiasmolithus grandis* Zone: Interval from the first occurrence of *Helicopontosphaera compacta* to the first occurrence of *Hayella situliformis. Discoaster saipanensis* and *Pedinocyclus larvalis* first appear near the base of this zone, and *Chiasmolithus grandis* apparently ranges no higher than the top of this zone. *Coronocyclus serratus* Hay, Mohler and Wade also first appears within this zone.

*Hayella situliformis* Zone: Interval from the first occurrence of *Hayella situliformis* to the first occurrence of *Isthmolithus recurvus. Chiasmolithus oamaruensis, Helicopontosphaera reticulata* and *Helicopontosphaera wilcoxonii* Gartner, n. sp., first appear near the base of this zone. The only record of *Corannulus germanicus* in the Blake Plateau cores is from this zone.

*Isthmolithus recurvus* Zone (emended): Interval from the first occurrence of *Isthmolithus recurvus* to the first abundant occurrence of *Sphenolithus predistentus.* Rare specimens of *Sphenolithus predistentus* and *Sphenolithus radians* have been recorded somewhat lower than the top of this zone, but these occurrences appear to be due to contamination.

*Sphenolithus predistentus—Discoaster barbadiensis* Zone: Interval from the first abundant occurrence of *Sphenolithus predistentus* to the last occurrence of *Discoaster barbadiensis.* The top of this zone is marked also by the last occurrence of *Discoaster saipanensis* and *Cyclococcolithina reticulata.*

The late middle Eocene and early part of the late Eocene interval are characterized by the development of many new species of nannofossils other than discoasters, which appear to have declined in prominence throughout most of the middle and upper Eocene. During the interval of the *Discoaster barbadiensis—Sphenolithus predistentus* Zone a balance seems to have been reached and few or no new species appeared. This is followed by an accelerating decline of diversity in the nannofossil assemblages and the successive extinction of many species during early Oligocene time.

The interval immediately above the extinction of *Discoaster barbadiensis* has been designated by Roth and Hay (*in* Hay, *et al.*, 1967) as the *Ellipsolithus subdistichus* Zone ( = *Ericsonia subdisticha* Zone of Baumann and Roth, 1969), and was defined as the interval from the last occurrence of *Discoaster barbadiensis* to the first occurrence of *Cyclococcolithina margaritae* (Roth and Hay). The base of this zone is readily recognized, as *Discoaster barbadiensis* is easily distinguished from all other upper Eocene discoasters. The top of the *Ellipsolithus subdistichus* Zone, however, is difficult to determine because *Cyclococcolithina margaritae* is a very small species and is not readily identifiable with a light microscope even at

its type level in JOIDES Blake Plateau core J–5.

An alternative zonal designation has been suggested by Bramlette and Wilcoxon (1967), who propose the name *Helicosphaera reticulata* (=*Helicopontosphaera reticulata*) Zone and indicate this zone as the interval from the top of the *Isthmolithus recurvus* Zone (of Hay, Mohler and Wade, 1965) to the last occurrence of *Helicopontosphaera reticulata.* According to Bramlette and Wilcoxon (1967) *Reticulofenestra umbilica* and *Cyclococcolithina formosa* (=*Cyclococcolithina lusitanica*) also become extinct at the top of the *Helicopontosphaera reticulata* Zone. (Hay, *et al.*, 1967, lowered the upper limit of the *Isthmolithus recurvus* Zone by defining it as the interval from the first occurrence of *Isthmolithus recurvus* to the last occurrence of *Discoaster barbadiensis.* This resulted in a downward expansion of the *Helicopontosphaera reticulata* Zone because the range of *Isthmolithus recurvus* extends above the extinction level of *Discoaster barbadiensis.*) The designation of Bramlette and Wilcoxon (1967) seems preferable for practical reasons; *Cyclococcolithina margaritae* is difficult or impossible to identify with a light microscope, as also is the next higher marker, *Reticulofenestra laevis* Roth and Hay, indicated by Roth (1968). The upper limit of the *Helicopontosphaera reticulata* Zone, on the other hand, corresponds closely to the extinction level of three easily identified species: *Helicopontosphaera reticulata, Reticulofenestra umbilica,* and *Cyclococcolithina formosa* (Kamptner), the last two being cosmopolitan species. Further modification of the zonation scheme of the uppermost Eocene-lower Oligocene interval should be expected, however, as a number of distinctive species become extinct in rapid succession during early Oligocene time (see also Hay, 1969).

In a recent study Martini (1969) has correlated the lower Oligocene, the type Lattorfian, with the *Ellipsolithus subdistichus* Zone, and the presence of *Cyclococcolithina formosa* and absence of *Discoaster barbadiensis* suggests that the Lattorfian correlates also with the *Helicopontosphaera reticulata* Zone. It is not clear, however, that the top of the Eocene corresponds to the extinction level of *Discoaster barbadiensis* because in all of Martini's sections the critical interval is lacking—represented by a hiatus, a sandy facies without nannofossils or not sampled. In any case, the problem of fixing the exact position of the Eocene-Oligocene boundary may be more imaginary than real because Eocene sediments which presumably overlie the extinction level of *Discoaster barbadiensis* are developed in only few localities and seem to represent a very short interval of time.

## VI. Biostratigraphic correlation of JOIDES cores J–3, J–4, and J–6B

On figure 2 the three Blake Plateau cores J–3, J–4 and J–6B are represented on a scheme of calcareous nannoplankton zones. It is clear that not the entire Paleocene-Eocene interval is represented. Much of the Paleocene section was not reached by coring, and only a small part of the upper Paleocene is represented by the 300′+ of Paleocene sediment recovered at site J–4.

No cores were recovered from the lowermost Eocene interval, which may be related directly to the presence of extensive cherty layers in the lower Eocene and in the lower part of the middle Eocene. It is worth noting that lower and middle Eocene cherts have been recovered from several locations in the North Atlantic during legs 1 and 2 of the Deep Sea Drilling Project, and that these cherts have been correlated with the prominent reflector Horizon A (see for example M.N.A. Peterson, *et al.*, 1970). Although Horizon A has not been identified seismically on Blake Plateau, Emery and Zarudzki (1967) noted that the top of the Paleocene can be correlated by a good reflecting horizon there. The presence of lower and middle Eocene cherts thus indicate that the conditions leading to the widespread silica deposition in the North Atlantic Ocean at this time were not confined to the deepest parts of the ocean basin.

The middle and upper Eocene intervals are represented in cores J–3 and J–6B in a more or less complete section. Some notable gaps are present, however, some of them clearly due to core loss, but the more significant gaps in the section are recognizable where cores were recovered continuously, as in cores J–3, between 504′ 11″ and 505′ 4″.

### J–4 (37° 02′N, 77° 43′W)

At site J–4 Paleogene sediments were

penetrated from about 270′ below the sediment surface down to about 585′. The sediments consist mostly of slightly lithified clayey limestone. Although more than 300′ of Paleogene section was penetrated, only a relatively short interval of time is represented, all within the late Paleocene (figure 3). The core recovery throughout this interval was sporadic, and there may be appreciable gaps between adjacent samples.

From 271′5″ down to about 470′ the *Discoaster multiradiatus* Zone is represented. Apparently the upper limit of this zone was not cored; however, within the section represented here two subzones can be distinguished. The lower subzone is marked by the presence of an unusual sphenolith, *Fasciculithus mitreus* Gartner, n. sp., and the upper subzone is marked by the presence of the distinctive species *Rhomboaster calcitrapa* Gartner, n. sp. These two subzones may be significant only locally, and there is as yet no evidence that such a subdivision is recognizable elsewhere. These two subzones were not recognized by Hay and Mohler (1967) in the same interval at Pont Labau in southern France.

From 480′ to 540′11″ the *Heliolithus riedeli* Zone is represented. *Sphenolithus anarrhopus* Bukry and Bramlette is characteristic of this zone, although not entirely restricted to it.

Below 540′11″ *Heliolithus riedeli* Bramlette and Sullivan is lacking and the remaining section is assigned to the *Discoaster gemmeus* Zone.

## J–3 (28°30′N, 77°31′W)

At site J–3 Paleogene sediments were recovered from about 500′ below the sediment surface down to the bottom of the borehole at about 585′. Blow (1969) places the Eocene-Oligocene boundary between 484 and 493′. Bramlette and Wilcoxon (1967) place the boundary slightly lower between 496 and 505′. According to the distribution chart (fig. 4) the interval above 504′11″ correlates with the *Helicopontosphaera reticulata* Zone, and from 504′11″ on down the interval is older.

The zonal succession appears somewhat disjointed and contains appreciable gaps. This may be because the sediments consist of interbedded chert, limestone, and calcareous ooze. Recovery was sporadic in this interval and contamination is probably not uncommon. Nevertheless several datums can be determined, although not every zone within the interval is recognizable. Between 503′5″ and 504′11″ the *Sphenolithus predistentus–Discoaster barbadiensis* Zone is represented. Between 504′11″ and 505′4″ there appears to be a significant hiatus because the interval from 505′4″ to 507′3″ represents the *Helicopontosphaera compacta–Chiasmolithus grandis* Zone. From 508′8″ to 515′3″ the *Bramletteius serraculoides* Zone is recognized, and the interval from 516′6″ to 517′6″ belongs to the *Reticulofenestra umbilica–Sphenolithus furcatolithoides* Zone. The *Discoaster tani* s.l.–*Sphenolithus radians* Zone is not recognizable in this core as *Discoaster tani* is present only higher in the section.

The *Chiphragmalithus quadratus* Zone extends from 519′6″ down to 538′2″, below which level about 15′ of core is missing. From 553′3″ to 555′ the *Discoaster sublodoensis* Zone is well developed, and the interval from 561′5″ to 569′10″ belongs to the *Discoaster lodoensis* Zone. No samples are available below 569′10″. The lowermost sample in this interval may have some older contaminants, but it is not clear whether actual penetration was below the *Discoaster lodoensis* Zone.

## J–6 (30°05′N, 79°15′W)

At site J–6 Paleogene sediments were cored from about 150′ below the sediment surface down to about 394′ where drilling was terminated. Saito and Lidz (*in* JOIDES, 1965, and *in* Schlee & Gerard, 1965) place the Eocene-Oligocene boundary at about 185′ below the sediment surface. This seems to be slightly in error, however, and the boundary is here placed between 151′6″ and 152′6″. Also, coring appears to have terminated within the lower Eocene without reaching Paleocene sediments.

The cored interval consists of calcareous ooze, fine grained limestone and chert. Core recovery below 200′ was sporadic, and there are several long intervals in which no samples were recovered.

The interval from 152′6″ through 157′8″ (fig. 5) is equivalent to the lower part of the *Helicopontosphaera reticulata* Zone, *i.e.* the uppermost upper Eocene. This zone ex-

tends up beyond 152′6″, and it is possible that the Eocene-Oligocene boundary may be even higher than indicated here.

The *Sphenolithus predistentus–Discoaster barbadiensis* Zone extends from 159′ down through 224′, and is well represented in this core. The interval from 230′1″ through 251′ is assignable to the *Isthmolithus recurvus* Zone.

The *Hayella situliformis* Zone is represented from 254′ through 264′. Between 264′ and 325′6″ no core was recovered, but the interval from 325′6″ to about 329′ is still assignable to the *Helicopontosphaera compacta–Chiasmolithus grandis* Zone, the zone immediately below the *Hayella situliformis* Zone. Between 332′ and about 360′ the calcareous nannofossils are of mixed ages. The interval is cherty and recovery was poor. Much of the middle and some of the lower Eocene section probably is missing. The remaining section is assignable to the *Discoaster lodoensis* Zone from about 360′ through 381′9″ and below this level the *Marthasterites tribrachiatus* Zone is recognizable.

## VII. Systematic Paleontology

### Genus Cruciplacolithus Hay & Mohler, 1967

### Cruciplacolithus staurion (Bramlette & Sullivan), n. comb.

*Coccolithus staurion* Bramlette & Sullivan, 1961, p. 141, pl. 2, fig. 5a–b, 6a–c; Sullivan, 1964, p. 181, pl. 3, fig. 2a–b, 3a–b; Sullivan, 1965, p. 32, pl. 3, fig. 7a–b.

Remarks: Hay & Mohler (*in* Hay, *et al.*, 1967) did not specifically assign this species to the genus *Cruciplacolithus,* but the definition of that genus must include this species. Some doubt remains about the phylogenetic accuracy of this assignment however, as the assignment is based purely on morphological criteria. Furthermore, the delicate crossbars in the center of this species may be broken out readily, and such a specimen would be placed in the genus *Coccolithus.*

### Genus Cyclococcolithina Wilcoxon, 1970

### Cyclococcolithina formosa (Kamptner)

*Cyclococcolithus formosus* Kamptner, 1963, p. 163, pl. 2, fig. 8, text fig. 20.
*Coccolithus lusitanicus* Black, 1964, p. 308, pl. 50, fig. 1, 2.
*Cyclococcolithus lusitanicus* (Black). Hay, Mohler & Wade, 1966, p. 390, pl. 7, fig. 3–6.
*Cyclococcolithus orbis* Gartner & Smith, 1967, p. 4, pl. 4.
*Cyclococcolithus lusitanicus* (Black). Bramlette & Wilcoxon, 1967, p. 103, pl. 3, fig. 16, 17.
*Cyclococcolithus formosus* Kamptner. Martini, 1969, p. 132, pl. 1, fig. 1, 2.
*Cyclococcolithina formosa* (Kamptner). Wilcoxon, 1970, p. 82.

Remarks: This species of *Cyclococcolithina* is easily recognized with the light microscope because of its distinctive interference figure in cross-polarized light.

Occurrence: *Cyclococcolithina formosa* first appears in lower Eocene sediments and persists throughout the middle and upper Eocene and into the lower Oligocene.

### Cyclococcolithina protoannula Gartner, n. sp.

Pl. 5, figs. 1a–c, 2

Description: Small to medium size species of *Cyclococcolithina* with large open center, narrow collar, and subequal narrow shields. The shields are constructed of about 45 slightly dextrally inclined elements. In cross-polarized light the collar of this species gives a strong interference figure, but the shield is less distinct. The proximal shield is slightly smaller than or the same size as the distal shield, and the periphery of the shields is nearly smooth.

Remarks: This species is similar to *Cyclolithella annula* (Cohen), but the latter lacks a distinct interference figure on the collar, and in electron micrographs the shield elements are more clearly visible.

Type specimen: Pl. 5, figs. 1a–c.

Type level: JOIDES core J–6B, 251′.

Occurrence: *Cyclococcolithina protoannula* may be found in abundance throughout the middle and upper Eocene, although its areal distribution may be environmentally controlled. In the Blake Plateau core J–6B it is common in the upper Eocene, but in core J–3 it may be scarce or lacking in the same interval.

### Genus Fasciculithus Bramlette & Sullivan, 1961

### Fasciculithus mitreus Gartner, n. sp.

Pl. 3; Pl. 4, fig. 1

Description: A mitre-shaped species of *Fasciculithus* with stellate or crudely polygonal cross section, concave base, and distally expanding body surmounted and terminated by a broad cone. The body is constructed of radially arranged tabular calcite crystallites which are separated by furrows at the periphery.

Remarks: *Fasciculithus mitreus* is similar to *Fasciculithus tympaniformis* but differs from that species in that it is commonly larger, expands distally, and has a distinct conical "top." *Fasciculithus schaubi* Hay and Mohler also is similar, but this latter species has a regularly pitted surface and a short stem.

Type specimen: Pl. 3, fig. 4.

Type level: JOIDES core J–4, 432′.

Occurrence: *Fasciculithus mitreus* occurs only in the lower part of the *Discoaster multiradiatus* Zone within the upper Paleocene interval.

## Genus HELICOPONTOSPHAERA Hay & Mohler, 1967

### HELICOPONTOSPHAERA RETICULATA (Bramlette & Wilcoxon), n. comb.

Pl. 1

*Helicosphaera reticulata* BRAMLETTE & WILCOXON, 1967, p. 106, pl. 6, fig. 15.

Remarks: *Helicopontosphaera reticulata* is broadly elliptical to rhomboidal in shape, the side opposite from the flaring rim commonly being nearly straight, although the remainder of the periphery may be more or less gently curved. The central disc, to which the flaring rim is attached, is also subrhomboidal with a pronounced two-part oblique bar across the center, on either side of which is a single, or, more often, double row of circular or elliptical pits. Although these pits may not be obvious in the light microscope to the casual observer, they can be seen readily in cross-polarized light and with interference contrast optics. The termination of the flaring rim may be broadly rounded or abrupt and pointed.

Occurrence: *Helicopontosphaera reticulata* first appears near the boundary between the middle and upper Eocene, and persists into the lower Oligocene. The species is not cosmopolitan and is not found in pelagic sediment from the deep ocean basins.

### HELICOPONTOSPHAERA WILCOXONII Gartner, n. sp.

Pl. 2

?*Helicosphaera* aff. *H. seminulum* Bramlette & Sullivan. BRAMLETTE & WILCOXON, 1967, p. 106, pl. 5, fig. 11, 12.

Description: Broadly elliptical species of *Helicopontosphaera* with relatively uniform peripheral flange which broadens rapidly at one end of the ellipse then terminates sharply. The central plate is regularly elliptical with two large openings in the center separated by a transverse bar, which may be aligned with the short axis of the ellipse, or may be inclined slightly to the axis. The crossbar is constructed of several discreet particles all of which have the same crystallographic orientation, but the crossbar is not continuous crystallographically with the shield.

Remarks: *Helicopontosphaera wilcoxonii* is similar to *Helicopontosphaera seminulum seminulum* but differs from that species in having the expanded flange terminated sharply rather than smoothly rounded as in the latter. *Helicopontosphaera* aff. *H. seminulum* of Bramlette & Wilcoxon (1967) also is similar but in that form too the flaring flange is more smoothly rounded. Very probably *Helicopontosphaera wilcoxonii* is a closely related form.

Type specimen: Pl. 2, fig. 2a, b.

Type level: JOIDES core J–6B, 233′ 1″.

Occurrence: *Helicopontosphaera wilcoxonii* first appears near the base of the upper Eocene within the *Hayella situliformis* Zone, and persists throughout the upper Eocene interval. It is best developed in Blake Plateau core, J–6B, but may be found rarely in core J–3 also.

## Genus MARKALIUS Bramlette & Martini, 1964

### MARKALIUS ASTROPORUS (Stradner)

*Cyclococcolithus astroporus* STRADNER *in* GOHRBANDT, 1963, p. 75, pl. 9, fig. 5–7; text-fig. 3–2a, b.

*Markalius inversus* (Deflandre) of BRAMLETTE & MARTINI, 1964, p. 302, pl. 2, fig. 4–9 (*not* pl. 7, fig. 2a, b); MARTINI, 1964, p. 49, pl. 6, fig. 9, 10.

*Markalius astroporus* (Stradner). HAY & MOHLER, 1967, p. 1528, pl. 196, fig. 32–35; pl. 198, fig. 2(?), 6.

*Markalius inversus* (Deflandre) of PERCH-

Nielsen, 1968, p. 72, pl. 24, fig. 1–8; pl. 25, fig. 1, text-fig. 35.
*Cyclococcolithus astroporus* Stradner. Radomski, 1968, p. 568, pl. 44, fig. 7, 8.
*Markalius inversus* (Deflandre) of Perch-Nielsen, 1969a, p. 326, text-fig. 5; Perch-Nielsen, 1969b, p. 63, pl. 3, fig. 5, 6.

Remarks: This medium to large size species has 33 to 36 elements per shield. With the light microscope a star may or may not be visible in the center of this species but with the electron microscope no stellate pore is visible. On some specimens radial ribs can be seen in the center, but on most a thin plate seemingly covers this structure (see also *Markalius inversus* (Deflandre)).

Occurrence: *Markalius astroporus* is most common in early Paleocene sediments, but has been recorded in reduced numbers from late Cretaceous, and middle and late Paleocene sediments as well.

### Markalius inversus (Deflandre)

*Cyclococcolithus leptoporus* var. *inversus* Deflandre *in* Deflandre & Fert, 1954, p. 150, pl. 9, fig. 4, 5.
*Cyclococcolithus inversus* (Deflandre). Hay, Mohler & Wade, 1966, p. 389, pl. 7, fig. 2.
*Cyclococcolithus* sp., Levin & Joerger, 1967, p. 166, pl. 1, fig. 10, 11.
*Cyclococcolithus inversus* (Deflandre). Haq, 1968, p. 24, pl. 8, fig. 1; Martini, 1969, p. 134, pl. 1, fig. 3, 4.

Remarks: The specimens which have been assigned to the species *Markalius inversus* (Deflandre) by various authors are readily divisible into three apparently natural groups on the basis of the number of shield elements. One group of specimens has between 33 and 36 elements per shield. These specimens all are from Paleocene (early and middle) and youngest Cretaceous samples, and very probably are conspecific with *Markalius astroporus* (Stradner). A second group of specimens has 27 or 28 elements per shield. This group includes the type specimen of *Markalius inversus,* and has been recorded from middle (?) and late Eocene deposits. The third group is characterized by relatively small specimens which have 19 to 21 elements per shield. This third group, as yet unnamed, has been reported only from late Eocene deposits. The specimens illustrated by Stradner & Edwards (1968), pl. 26, fig. 2, pl. 27, fig. 3–6 belong to this last group. Of the other specimens illustrated by Stradner & Edwards (1968) the specimen on pl. 26, fig. 1 probably belongs to the species *Pedinocyclus larvalis* (Bukry & Bramlette); that specimen on pl. 27, figs. 1, 2 cannot be assigned definitely because the number of shield elements is not discernible.

Occurrence: Although *Markalius inversus* has been reported from middle and late Eocene strata, all illustrations of this species are from late Eocene samples. As three distinct species probably have been grouped under this name, it is not possible to establish the range of the species at this time. Data gathered by the author indicate that *Markalius inversus* may be found sporadically as early as the late middle Eocene, but is encountered regularly, though sparsely, only in late Eocene strata.

## Genus Reticulofenestra Hay, Mohler & Wade, 1966

### Reticulofenestra umbilica (Levin)

*Coccolithus*? sp., Bouché, 1962, p. 84, pl. 1, fig. 17(?), 21a, b, 22(?).
*Coccolithus placomorphus* (Kamptner) of Stradner, 1964, p. 135, text-fig. 10.
?*Ellipsoplacolithus* sp., Bachmayer, 1964, p. 184, pl. 2, fig. 10.
*Coccolithus*? sp., Cohen, 1965, p. 13, pl. 1, fig. h, i.
*Coccolithus umbilicus* Levin, 1965, p. 265, pl. 41, fig. 2.
*Reticulofenestra caucasica* Hay, Mohler & Wade, 1966, p. 386, pl. 2, fig. 5 (*not* fig. 6–8); pl. 3, fig. 1, 2; pl. 4, fig. 1, 2.
*Apertapetra samodurovi* Hay, Mohler & Wade, 1966, p. 387, pl. 6, fig. 1–3 (*not* fig. 4–7).
*Coccolithus pelicomorphus* Reinhardt, 1967, p. 206, pl. 1, fig. 10, 11, 14; pl. 5, fig. 10; pl. 7, fig. 4, text-fig. 6.
*Apertapetra umbilicus* (Levin). Levin & Joerger, 1967, p. 166, pl. 1, fig. 9a–c; Bramlette & Wilcoxon, 1967, p. 101, pl. 5, fig. 1, 2.
*Reticulofenestra placomorpha* (Kamptner) of Stradner & Edwards, 1968, p. 22, pl. 19?; 20 (*not* pl. 21, probably *not* pl. 22, fig. 1, 2, 3); pl. 23?; 24; 25, fig. 1?, 2; Haq, 1968, p. 29, pl. 5, fig. 1–5; pl. 3, fig. 3.

Remarks: Stradner & Edwards (1968) synonymize this form with *Tremalithus placomorphus* Kamptner from the Tortonian (Miocene) of the Vienna basin. However, there are significant differences between the two species. *Reticulofenestra umbilica* has approximately 100 elements per shield whereas *Tremalithus placomorphus* has only

about 70 elements. The large number of elements in the former species and the consequent small size of the elements makes them unresolvable with light optics. Similarly the delicate laths and grillwork in the center of *Reticulofenestra umbilica* are not visible with light optics. It is very unlikely, therefore, that Kamptner's specimen of *Tremalithus placomorphus* is identical with *Reticulofenestra umbilica.* In addition *Reticulofenestra umbilica* has been reported only from middle Eocene to early Oligocene deposits, and is notably absent from post early Oligocene sediments (see for example Bramlette & Wilcoxon, 1967). Kamptner's specimens, therefore, would have to be reworked and although reworking of calcareous nannofossils is not uncommon, it seems imprudent to select as the nomenclatural type of a species a specimen which is, at best, atypical and reworked.

Stradner & Edwards' concept of this species also seems broader than is necessary or desirable. The specimens illustrated on pl. 21, figs. 1 & 2 are readily assignable to *Reticulofenestra scissura* Hay, Mohler and Wade, a species easily identified in both light and electron microscope.

*Reticulofenestra umbilica* very probably developed from the middle Eocene species *Coccolithus marismontium* Black from which species it differs primarily by its larger size and relatively larger central opening. This last feature, however, is highly variable in *Reticulofenestra umbilica* and probably not a reliable criterion. *Coccolithus marismontium* apparently also is the ancestor of *Coccolithus floridanus* Roth & Hay ( = *Cyclococcolithus neogammation* Bramlette & Wilcoxon), which ranges from the upper part of the middle Eocene well into the Miocene.

Occurrence: *Reticulofenestra umbilica* first appears in middle Eocene sediments and is a common element of the assemblage through most of the middle and upper Eocene interval. The species is also present in earliest Oligocene sediments, but its numbers diminish as it becomes extinct.

### Reticulofenestra scissura Hay, Mohler & Wade

*Reticulofenestra scissura* Hay, Mohler & Wade, 1966, p. 387, pl. 5, fig. 1, 5, 6? (*not* fig. 2, 3, 4).
*Syracosphaera bisecta* Hay, Mohler & Wade, 1966, p. 393, pl. 10, fig. 1–6.
*Coccolithus* cf. *C. scissurus* (Hay, Mohler & Wade). Bramlette & Wilcoxon, 1967, pl. 102, pl. 4, fig. 1, 2.
*Coccolithus bisectus* (Hay, Mohler & Wade). Bramlette & Wilcoxon, 1967, pl. 102, pl. 4, fig. 11–13.
*Reticulofenestra dictyoda* (Deflandre & Fert) of Stradner & Edwards, 1968, p. 19, pl. 12, fig. 3? only; pl. 13, pl. 22, fig. 4.
*Reticulofenestra placomorpha* (Kamptner) of Stradner & Edwards, 1968, p. 22 (in part), pl. 21.
*Stradnerius dictyodus* (Deflandre & Fert) of Haq, 1968, p. 31, pl. 2, fig. 5–8.

Remarks: Hay, Mohler & Wade illustrated *Reticulofenestra scissura* with electron micrographs only in proximal view, and their light micrographs represent either an aberrant specimen or an entirely different species. On the other hand, they illustrated *Syracosphaera bisecta* only in distal view, and the light micrographs of this species probably are quite accurate. The illustrations of Haq demonstrate convincingly the true nature of the proximal and distal surface of this placolith, *i.e.* the irregular reticulate network in the proximal surface of the central pore, and the large, roughly radial plates on the distal surface of the central pore. It is surprising, therefore, that Stradner & Edwards, and Haq identify the above species with *Discolithus dictyodus* Deflandre & Fert which species clearly does not have the large radial plates on the distal surface of the central pore. The two different forms illustrated

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## Plate 1

*Helicopontosphaera reticulata* (Bramlette & Wilcoxon). Gartner, n. comb.

Figure 1, 3. Electron micrographs, × 10,000. 1—J–6B, 251′; 3—Shubuta Clay, Clark Co., Mississippi.

Figure 2a–c. Light micrographs, × 2500, J–6B, 182′1″. 2a—phase contrast; 2b—interference contrast; 2c—cross-polarized light.

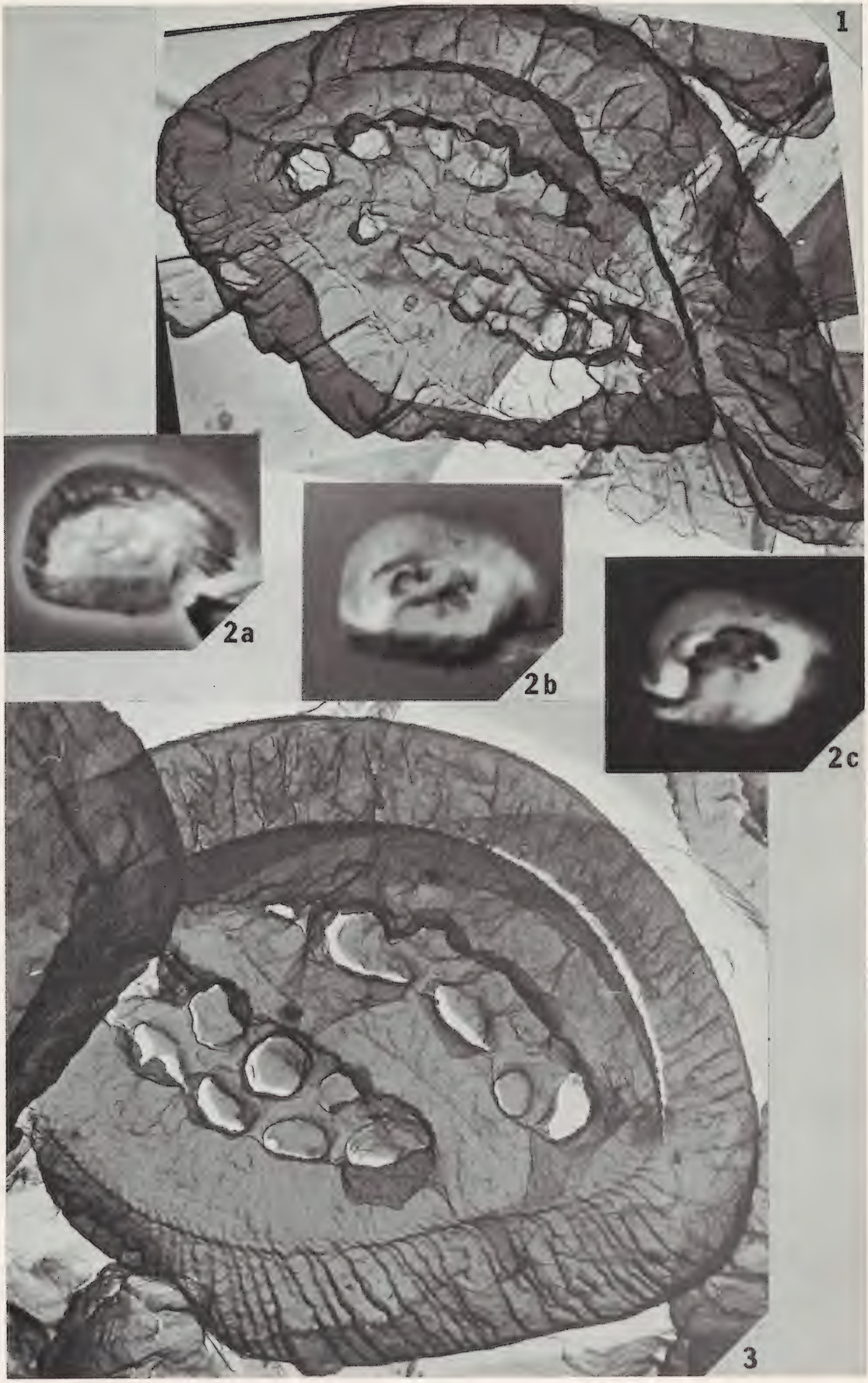


PLATE 1

by Bramlette & Wilcoxon, and assigned by them to different species appear to fall within the range of variation of *Reticulofenestra scissura,* a conclusion supported by their similar stratigraphic range.

Occurrence: *Reticulofenestra scissura* first appears in the middle Eocene and persists as a significant constituent of the assemblage into the Oligocene, finally becoming extinct within the *Sphenolithus ciperoensis* Zone (see Bramlette & Wilcoxon, 1967).

## Genus RHOMBOASTER Bramlette & Sullivan, 1961

### RHOMBOASTER CALCITRAPA Gartner, n. sp.
Pl. 4, figs. 2–6

Description: *Rhomboaster* on which some or all of the eight corners have long spines developed which extend roughly radially and taper to a point. The spines commonly are slightly curved and somewhat irregular in their orientation, so that they may extend at an unusual angle from the corner of the rhomb. In ultrastructure *Rhomboaster calcitrapa* resembles most closely certain asteroliths in that no discrete crystallographic units can be recognized and the entire object appears to be built up by the deposition of successive layers of calcite.

Remarks: *Rhomboaster calcitrapa* differs from *Rhomboaster cuspis* Bramlette & Sullivan in having long irregularly oriented spines developed on its corners. The Cretaceous genus *Micula* is similar but probably unrelated to this form.

Type specimen: Pl. 2, fig. 3.

Type level: JOIDES core J–4, 300′4″.

Occurrence: *Rhomboaster calcitrapa* is a conspicuous constituent of the assemblage in the upper part of the *Discoaster multiradiatus* Zone in the JOIDES Blake Plateau core J–4.

## Genus SPHENOLITHUS Deflandre, 1952

### SPHENOLITHUS STELLATUS Gartner, n. sp.
Pl. 5, figs. 3a, b

Description: Sphenolith with stellate outline, consisting of six segments arranged radially each segment having a different crystallographic orientation. Adjacent segments are joined along a radial suture, and the length of each segment is at least twice the length of the sutures. At the periphery the segments are evenly tapered and pointed.

Remarks: *Sphenolithus stellatus* superficially resembles small asteroliths but is readily distinguished from them in cross-polarized light. It differs from all species of *Sphenolithus* by the regular stellate outline and by the small number of radially arranged segments.

Type specimen: Pl. 5, figs. 3a, b.

Type level: JOIDES core J–6B, 251′.

Occurrence: *Sphenolithus stellatus* was recorded only from the middle Eocene interval of the JOIDES Blake Plateau core J–3.

## Genus TOWEIUS Hay & Mohler, 1967

### TOWEIUS EMINENS (Bramlette & Sullivan), n. comb.

*Coccolithus eminens* BRAMLETTE & SULLIVAN, 1961, p. 139, pl. 1, fig. 3a–d; SULLIVAN, 1964, p. 181, pl. 1, fig. 11a, b; SULLIVAN, 1965, p. 31.

*Cruciplacolithus eminens* (Bramlette & Sullivan). HAY & MOHLER, 1967, p. 1527, pl. 196, fig. 26–28 (*not* p. 198, fig. 9, 10).

*Coccolithus eminens* Bramlette & Sullivan. RADOMSKI, 1968, p. 564, pl. 45, fig. 7, 8.

Remarks: This species resembles *Toweius craticulus* Hay & Mohler in both optical properties (interference figure in cross-polarized light) and in ultrastructure, except in one distinguishing characteristic: *Toweius eminens* has only four pores in the center. These pores are larger than the 8 to 12 pores in *Toweius craticulus* and are symmetrically arranged in the center of the placolith. The bars separating these four pores, although

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## PLATE 2

*Helicopontosphaera wilcoxonii* Gartner, n. sp

Figure 1, 4. Electron micrographs, × 10,000, J–6B, 251′.

Figure 2a, b, 3. Light micrographs, × 2500. 2a, b—J–6B, 233′1″; 2a—interference contrast; 2b—cross-polarized light. 3—J–6B, 251′, interference contrast.

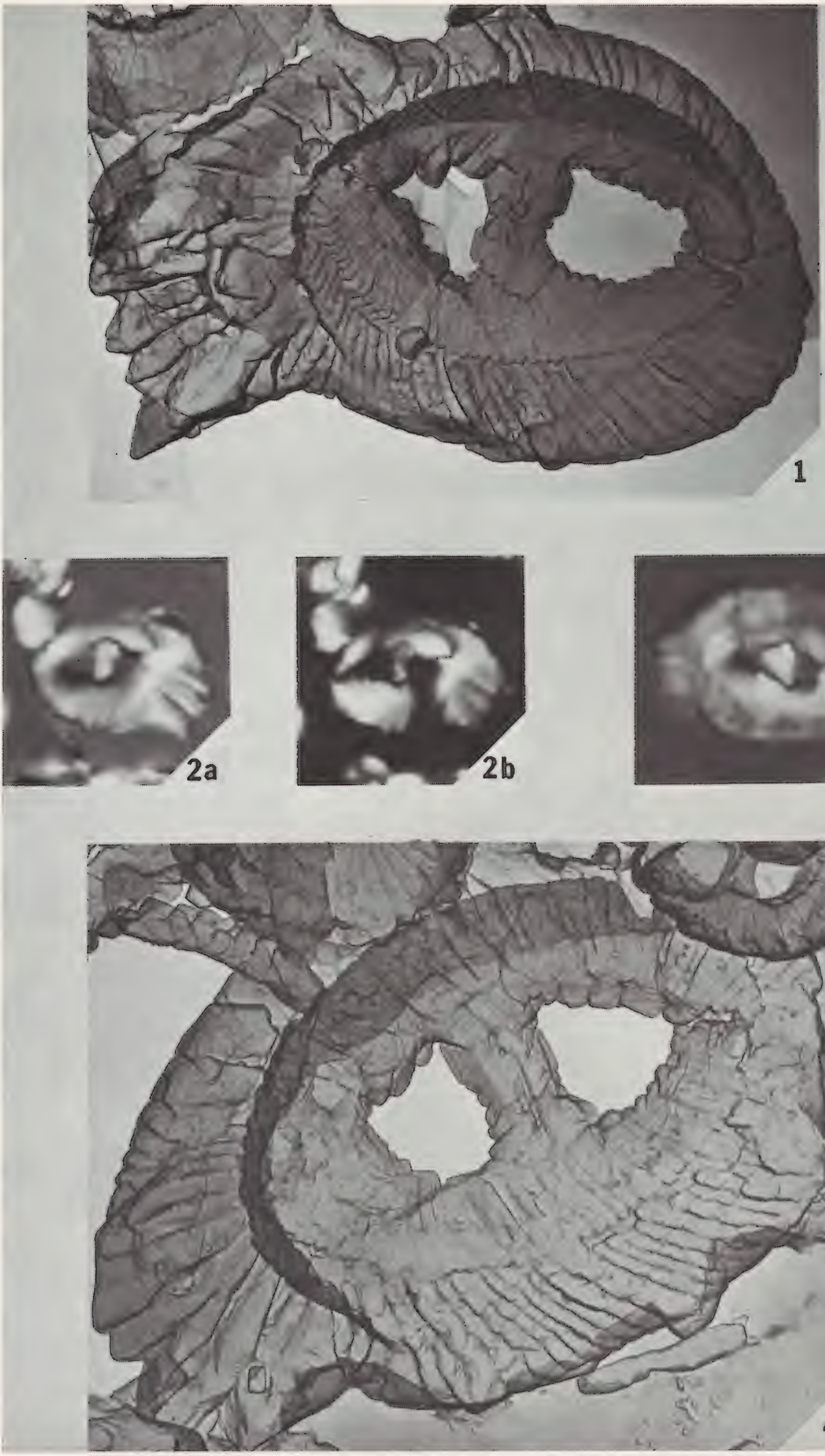


PLATE 2

analogous to the crossbars in *Cruciplacolithus,* are not homologous in a biological sense because in *Toweius eminens* the crossbars developed from the central plug and radiating bars of *Toweius craticulus,* whereas the crossbars of *Cruciplacolithus* (i.e. *Cruciplacolithus tenuis* (Stradner)) developed from the peculiar grillwork exhibited by the Cretaceous genus *Sollasites.*

Occurrence: *Toweius eminens* first appears near the top of the *Discoaster gemmeus* Zone and persists into the basal Eocene *Marthasterites contortus* Zone.

## Nomenclatural Note

The following names, used on the accompanying charts but not mentioned in the text, are new combinations not used validly in previous publications. One name is newly proposed as a substitute for a homonym.

*Cyclolithella bramletti* (Hay & Towe), n. comb. = *Cyclolithus bramlettei* Hay & Towe, 1962, p. 500, pl. 5, fig. 6, pl. 7, fig. 2.

*Discolithina ocellata* (Bramlette & Sullivan), n. comb. = *Discolithus ocellatus* Bramlette & Sullivan, 1961, p. 142, pl. 3, figs. 2a–c.

*Helicopontosphaera parallela* (Bramlette & Wilcoxon), n. comb. = *Helicosphaera parallela* Bramlette & Wilcoxon, 1967, p. 106, pl. 5, figs. 9, 10.

*Helicopontosphaera seminulum lophota* (Bramlette & Sullivan), n. comb. = *Helicosphaera seminulum lophota* Bramlette & Sullivan, 1961, p. 144, pl. 4, figs. 3a, b, 4.

*Transversopontis exilis* (Bramlette & Sullivan), n. comb. = *Discolithus exilis* Bramlette & Sullivan, 1961, p. 142, pl. 2, figs. 10 a–c.

*Marthasterites nunnii,* nom. nov., substitute name for *Marthasterites bramlettei* Brönnimann & Stradner, 160, p. 366, figs. 17–20, 23, 24 (junior homonym; see Loeblich & Tappan, 1966, p. 148).

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## Plate 3

*Fasciculithus mitreus* Gartner, n. sp.

Figure 1, 2. Electron micrographs, × 10,000, J–4, 432′. 1—side view; 2—proximal view (concave side).

Figure 3a, b; 4a–c. Light micrographs, × 2500. 3a, b—J–4, 321′, side view. 3a—interference contrast; 3b—cross-polarized light. 4a–c—J–4, 392′; 4a—side view, interference contrast; 4b—distal view (convex side), phase contrast; 4c—distal view (convex side), cross-polarized light.

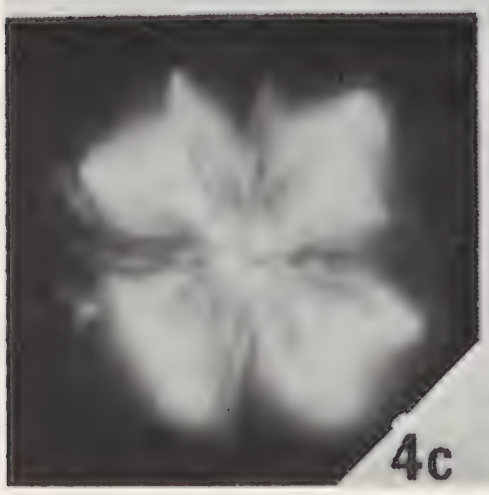
3a

3b

1

4a

4b


4c

2

PLATE 3

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## Plate 4

Figure 1. *Fasciculithus mitreus* Gartner, n. sp. Electron micrograph, × 10,000, J–4, 432′. Distal view (convex side).

Figure 2–6. *Rhomboaster calcitrapa* Gartner, n. sp. J–4, 300′4″.
2–4. Electron micrographs, × 5000.
5, 6a, b. Light micrographs, × 2500. 5, 6b—dark field illuminations; 6a—transmitted light.

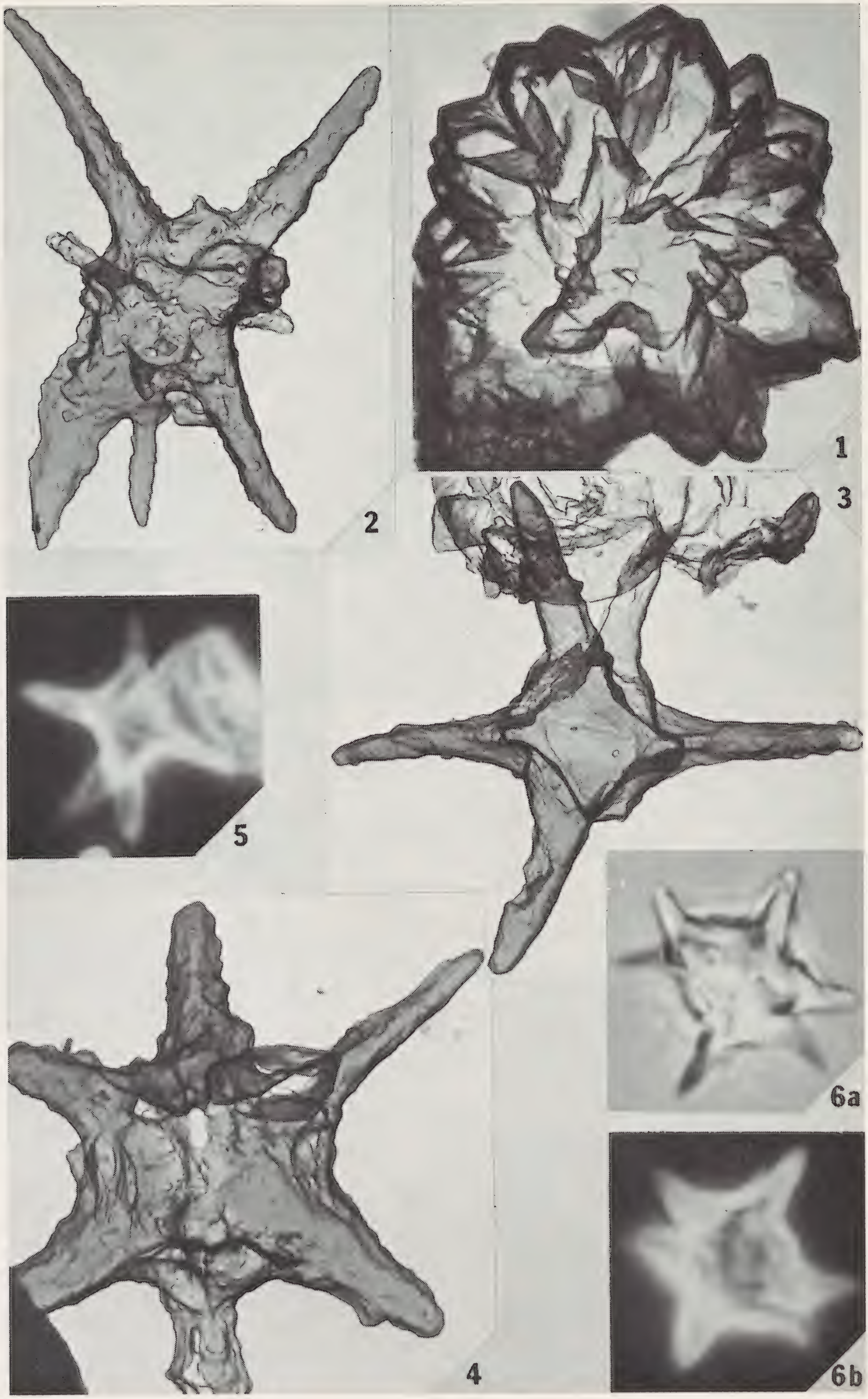


PLATE 4

phoriden: Monatsber. Deutsch. Akad. Wiss. Berlin, v. 10, p. 220–229, 2 pls.

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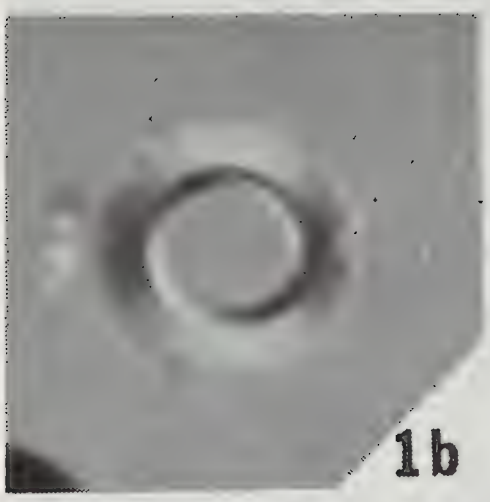
## Plate 5

Figure 1, 2. *Cyclococcolithina protoannula* Gartner, n. sp., J–6B, 251′.
1a–c. Light micrographs, × 2500. 1a—phase contrast; 1b—interference contrast; 1c—cross-polarized light. 2—Electron micrograph, × 10,000.

Figure 3a, b. *Sphenolithus stellatus* Gartner, n. sp., J–6B, 251′. 3a—Interference contrast; 3b—cross-polarized light.

Figure 4–6. *Toweius eminens* (Bramlette & Sullivan). Gartner, n. comb., J–4, 531′2″.
4a–c, 5. Light micrographs, × 2500. 4a—phase contrast; 4b—transmitted light; 4c, 5—cross-polarized light. 6—Electron micrograph, × 10,000. Distal view.

1a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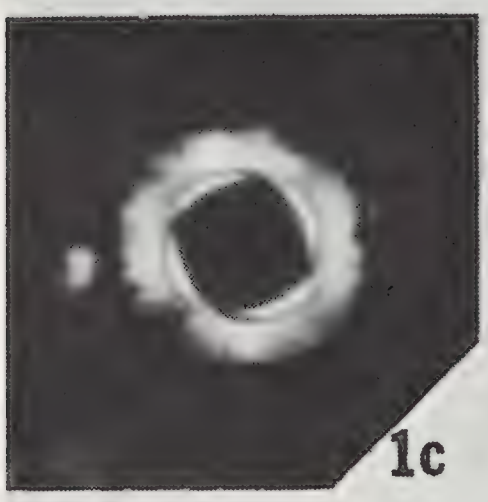
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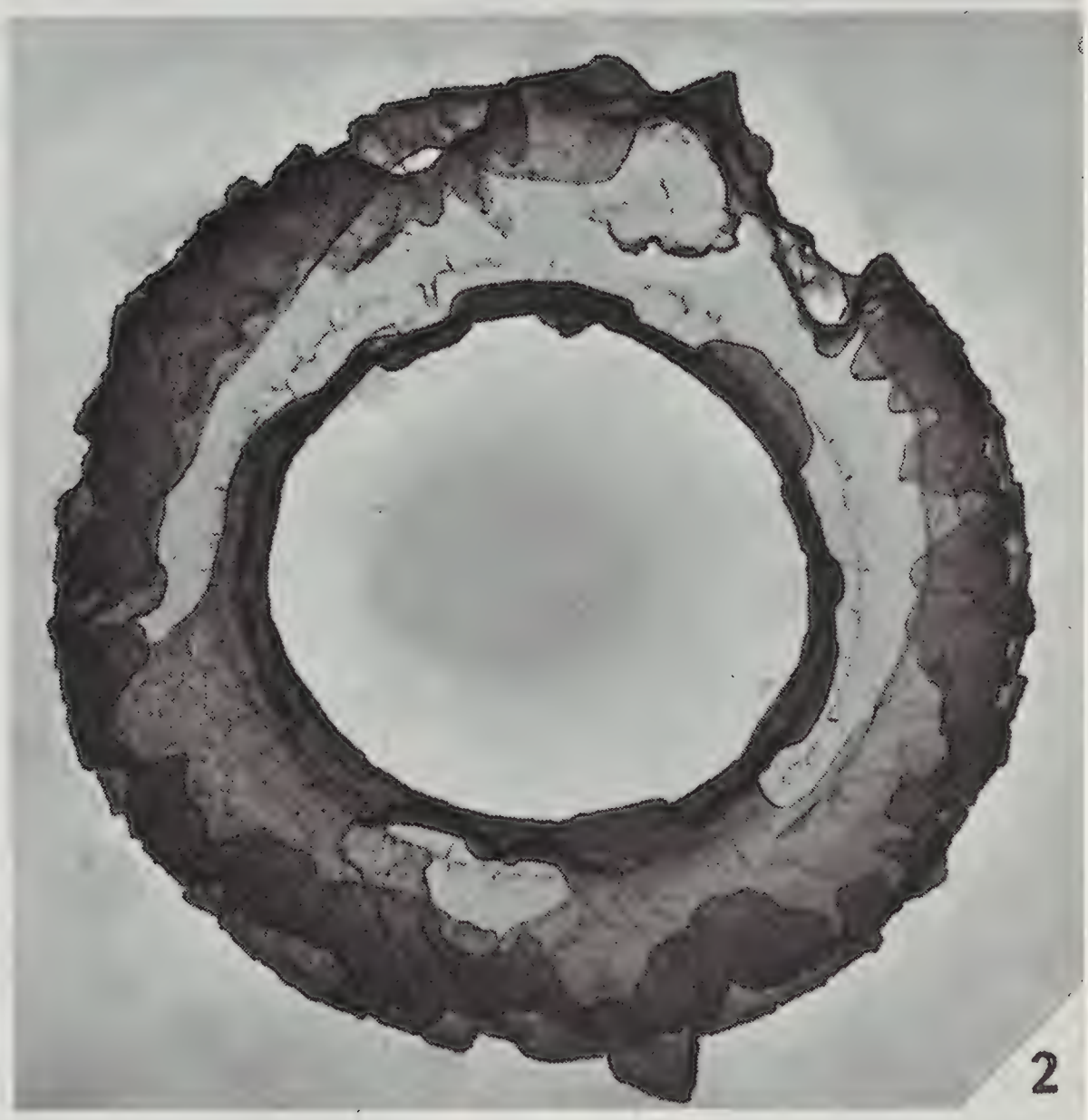
3a

3b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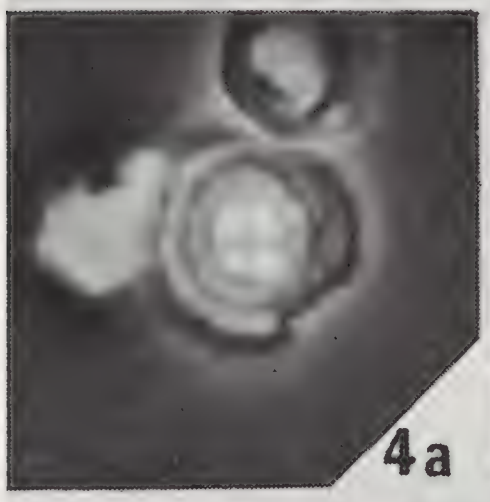
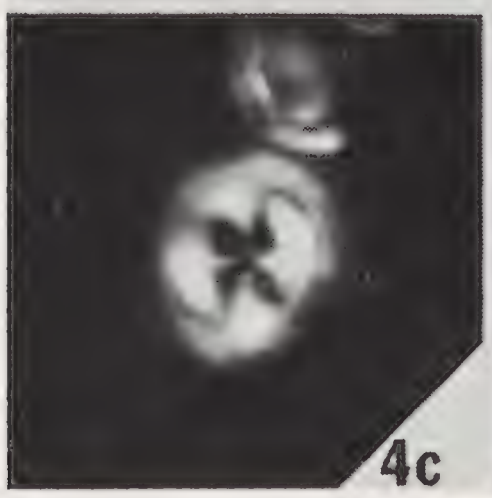

4a

4h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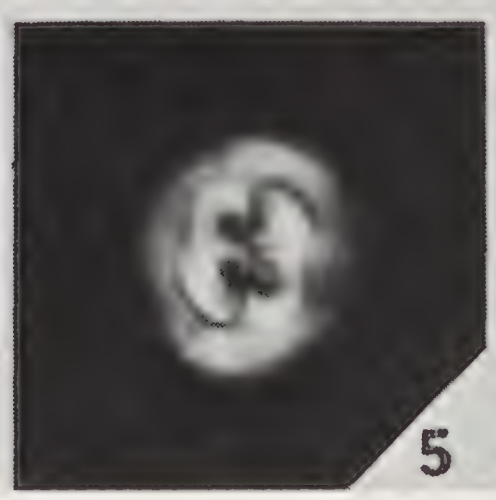
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6

PLATE 5

# VALIDATION OF *PEDINOCYCLUS* AND *QUINQUERHABDUS*, NEW CALCAREOUS NANNOPLANKTON GENERA[1]

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Validation of the names of these two calcareous nannoplankton genera is necessary because generic diagnosis was not given in Bukry and Bramlette (1969) and because a proposed new genus name, *Leptodiscus,* has been determined to be preoccupied by a dinoflagellate (*Leptodiscus* Hertwig, 1877). We thank Dr. Alfred R. Loeblich, Jr., for bringing this to our attention.

PEDINOCYCLUS Bukry and Bramlette, n. gen.

*Description*: Circular coccoliths constructed as a single thin, nearly flat shield, composed of slightly inclined to radial elements that are not clearly imbricate. Central opening relatively small.

*Type species*: *Leptodiscus larvalis* Bukry and Bramlette, 1969, Tulane Studies Geology and Paleontology, 7 (3/4), p. 134, pl. 2, figs. 8–11.

*Remarks*: Little imbrication of the elements of the single thin, flat shield distinguish *Pedinocyclus* from the individual shields of *Cyclococcolithus* Kamptner, 1954, or *Calcidiscus* Kamptner, 1950.

QUINQUERHABDUS Bukry and Bramlette, n. gen.

*Description*: Pentaliths with five long, blade-like elements tapering abruptly upward from the heavy and centrally depressed base. The characteristic optical orientation of the five segments in basal view shows the typical orientations of braarudosphaerids, although not clearly because of the high upward taper.

*Type species*: *Quinquerhabdus colossicus* Bukry and Bramlette, 1969, Tulane Studies Geology and Paleontology, 7 (3/4), p. 138, pl. 3, figs. 1–4.

*Remarks*: The abrupt taper of blades from the pentalith base to a pointed tip distinguishes *Quinquerhabdus* from species of *Braarudosphaera* Deflandre, 1947, and *Micrantholithus* Deflandre, 1950.

## REFERENCE

BUKRY, D., and M. N. BRAMLETTE, 1969, Some new and stratigraphically useful calcareous nannofossils of the Cenozoic: Tulane Stud. Geol. Paleont., v. 7, p. 131–142.

[1] Publication authorized by the Director, U. S. Geological Survey.



## RECENT BOOK

INTRODUCTION TO MINERALOGY, by Carl W. Correns. Published by Springer-Verlag, New York Inc., 1969, xii + 484 pp., illus., $12.40

This is a comprehensive text in Mineralogy at the introductory level, including the basic principles of crystallography, petrology and geochemistry. The book is divided into three parts: I—Crystallography, including crystal chemistry, crystal physics, structural mineralogy and crystal growth; II—Petrology, including processes of magmatism, weathering, sedimentation, and metamorphism as well as geochemical aspects of the structure of the earth and the distribution of the elements; and III—in which the descriptive mineralogy and crystallography are summarized with crystallographic, crystal chemical, mineralogical, and petrographic tables (including chemical analyses). The text is well illustrated with drawings, photographs and photomicrographs.

# NEW TERTIARY CALCAREOUS NANNOFOSSILS[1]

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### ABSTRACT

Stratigraphic studies of Tertiary calcareous nannofossil assemblages from the JOIDES Deep Sea Drilling Project and Blake Plateau cores and from some outcrop localities in North America have indicated many undescribed nannofossil taxa, of which 27 are described here. The new taxa described include: *Campylosphaera eodela, Ceratolithina? vesca, Ceratolithus amplificus, Ceratolithus primus, Chiasmolithus altus, Cyclolithella pactilis, Dictyococcites abisectus* (n. comb.), *Dictyococcites bisectus* (n. comb.), *Dictyococcites scrippsae, Discoaster bellus, Discoaster mohleri, Discoaster prepentaradiatus, Discoaster variabilis pansus, Discoasteroides bramlettei, Discolithina latoculata, Discolithina segmenta, Ellipsolithus lajollaensis, Fasciculithus magnus, Helicopontosphaera granulata, Lophodolithus acutus, Lophodolithus rotundus, Micrantholithus articulatus, Reticulofenestra samodurovi* (n. comb.), *Reticulofenestra hillae, Scyphosphaera expansa, Scyphosphaera globulata, Sphenolithus capricornutus, Sphenolithus dissimilis, Syracosphaera? wechesensis,* and *Vermiculithina arca.*

[1] Publication authorized by the Director, U. S. Geological Survey.

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## I. Introduction

Stratigraphic age determinations based on calcareous nannofossil assemblages have provided valuable data to guide coring operations of the Deep Sea Drilling Project from the D/V *Glomar Challenger.* The resistance to solution, diversity, and abundance of this group of fossils has contributed to their stratigraphic usefulness. In the course of stratigraphic studies of cores from Leg 1 and Leg 3 (Gulf of Mexico and Atlantic Ocean), and Leg 6 (Pacific Ocean) of the Deep Sea Drilling Project, several new taxa of calcareous nannofossils have been recognized. Comparative studies of nannofossil assemblages from Gulf Coastal Plain, Blake Plateau and California samples have led to recognition of new taxa and to additional information on nearshore and open-ocean aspects of nannofossil assemblages.

The most striking contrast between calcareous nannofossil assemblages from neritic and open-ocean depositional localities is seen in Eocene material that contains greatly diversified neritic assemblages. Commonly occurring are species of *Discolithina, Isthmolithus, Micrantholithus, Polycladolithus, Rhabdosphaera, Transversopontis, Zygolithus,* and holococcolith taxa. In the Eocene assemblages sampled by DSDP Leg 3 in the South Atlantic Ocean and by DSDP Leg 6 in the northwestern Pacific Ocean, only a few species of such taxa are represented (sparse *Isthmolithus recurvus* and *Zygolithus dubius*). The reduced taxonomic diversity in the open-ocean assemblages is the result of solution or ecologic exclusion. The rare occurrence of *I. recurvus* in deep-ocean samples and its contrasting common occurrence in neritic samples indicates that whereas the taxon was cosmopolitan, it was more susceptible to solution in the deep ocean. On the other hand, taxa such as *Polycladolithus* and *Transversopontis* are absent from open-ocean deposits, whether shallow or deep, and were probably ecologically restricted to neritic areas of deposition.

As more taxa are described and their geographic and geologic occurrences are recorded, the identification of ecologic and solution controls on assemblages will contribute to further refinement of the stratigraphic interpretations of calcareous nannofossils.

Some of the new taxa described here have been identified from both oceanic cores and land-outcrop localities, thereby indicating their wide geographic range and good preservability. For instance, *Campylosphaera eodela, Chiasmolithus altus, Dictyococcites abisectus, Dictyococcites bisectus, Dictyococcites scrippsae, Discoaster mohleri, Discoasteroides bramlettei, Discolithina segmenta, Reticulofenestra hillae,* and *Sphenolithus dissimilis* are present in open-ocean and land-outcrop samples. New taxa presently known only from open-ocean samples include *Ceratolithus amplificus, Ceratolithus primus, Cyclolithella pactilis, Discoaster bellus, Discoaster prepentaradiatus, Discoaster variabilis pansus, Fasciculithus magnus, Helicopontosphaera granulata, Scyphosphaera globulata, Sphenolithus capricornutus,* and *Vermiculithina arca.* The ranges of these taxa are likely to be increased as detailed studies of land-outcrop areas are undertaken. Some species, such as *Ceratolithina? vesca, Discolithina latoculata, Ellipsolithus lajollaensis, Lophodolithus acutus, Lophodolithus rotundus, Micrantholithus articulatus, Scyphosphaera expansa,* and *Syracosphaera? wechesensis*, are known from only a few localities but they are morphologically distinctive and could prove useful in stratigraphic and paleoecologic determinations. *S.? wechesensis*, for example, is common in certain middle Eocene land outcrops in Texas, U.S.A., and the Caucasus, U.S.S.R., but has not been recognized in ocean cores. It may be an indicator of shallow water or nearshore depositional environment.

## II. Acknowledgment

Most of the oceanic-core samples examined in the preparation of this paper were provided by the National Science Foundation through the Deep Sea Drilling Project. Many of the outcrop samples were made available by M. N. Bramlette, Scripps Institution of Oceanography, who suggested the need for description of some of these species and provided valuable discussion on the taxonomic status of *Dictyococcites bisectus.* We thank R. G. Douglas and M. N. Bramlette for constructive review of this paper.

## III. Systematic Paleontology

### Genus Campylosphaera Kamptner, 1963

#### Campylosphaera eodela
Bukry and Percival, n. sp.
Pl. 1, figs. 1–4

*Description*: This small species is characterized by a broad, subrectangular rim outline and a central opening that is largely filled by a cross structure aligned with the long and short axes of the coccolith. The rim cycle is composed of about 30 elements; in cross-polarized light, the rim is faint, with the margin at the central area being brightest. The cross is also faint in cross-polarized light.

*Remarks*: *Campylosphaera eodela* is distinguished from *Campylosphaera dela* (Bramlette and Sullivan) by its smaller size, more elongate shape, and corresponding smaller central opening with respect to rim width. *Campylosphaera eodela* is distinguished from species of *Cruciplacolithus* by subrectangle shape, and curving of the rim in side view and faint appearance of cross structure in cross-polarized light. This form was mentioned by Bramlette and Sullivan (1961) as a possible subspecies of *C. dela.*

*Occurrence*: *Campylosphaera eodela* has wide geographic range, occurring in samples from the Atlantic and Pacific Oceans and from California and Trinidad. Stratigraphically it has a limited range of upper Paleocene. It is best developed in the upper part of the *Discoaster multiradiatus* Zone.

*Size*: 6 to 10 microns.

*Holotype*: USNM 169171 (Pl. 1, figs. 1–2).

*Paratypes*: USNM 169172 and 169173.

*Type locality*: JOIDES core 4, 84 meters, Blake Plateau, Atlantic Ocean.

### Genus Ceratolithina Martini, 1967

#### Ceratolithina? vesca
Bukry and Percival, n. sp.
Pl. 1, figs. 5–8

*Description*: This small asymmetric species has one straight and narrow arm and one slightly curved and thicker arm. The narrow arm is the shorter and is tapered from the pointed tip, whereas the broad arm tapers only near the tip. The arms meet at an 80° to 90° angle and both arms are part of one crystallographic unit. In cross-polarized light this species shows maximum brightness when the arms are parallel to the directions of polarization.

*Remarks*: *Ceratolithina? vesca* is distinguished from species of *Ceratolithina* Martini and *Ceratolithus* Kamptner by the much wider angle formed by the arms and by the smaller arch. *Ceratolithina? vesca* is distinguished from *Ceratolithoides kamptneri* Bramlette and Martini by being a single crystallographic unit instead of each arm being a distinct unit.

*Occurrence*: *Ceratolithina? vesca* occurs abundantly in certain upper middle Eocene samples from the Hospital Hill Marl in Trinidad. It is also present in a sample of approximately equivalent age from southwestern U.S.S.R. (M. N. Bramlette, personal commun., 1970).

*Size*: 6 to 10 microns.

*Holotype*: USNM 169174 (Pl. 1, figs. 5–6).

*Paratype*: USNM 169175.

*Type locality*: Type locality of *Porticulosphaera mexicana* Zone of Bolli (1957b), Navet Formation, Hospital Hill Marl, Trinidad.

### Genus Ceratolithus Kamptner, 1950

#### Ceratolithus amplificus
Bukry and Percival, n. sp.
Pl. 1, figs. 9–11

*Description*: This basically horseshoe-shaped species has a broadly pointed extension on the outer part of the arch. One arm, generally that bearing a row of simple tooth-like structures, is straighter than the other, which has a slight inward bend toward the tip. In cross-polarized light this subspecies is moderately bright (moderate birefringence in plan view).

*Remarks*: The external shape and crystallographic orientation of *Ceratolithus amplificus* are intermediate between those of *Ceratolithus tricorniculatus*, which has a horn-like extension and slender curved arms but is wholly dark (no birefringence) in cross-polarized light, and those of *Ceratolithus rugosus*, which lacks a horn-like extension, has thick arms, but is very bright in cross-polarized light (high birefringence) when oriented in plan view at 45° to the direction of polarization. *C. amplificus* is probably a transitional form between those

two species, distinguished by its horned arch and moderately bright appearance in cross-polarized light.

*Occurrence*: The stratigraphic occurrence of *C. amplificus*, in the uppermost Miocene and lower Pliocene assemblages of the *Ceratolithus rugosus* Zone, agrees with the transitional morphology of this species as *C. rugosus* first occurs in this zone and completely replaces *C. tricorniculatus* in strata above this level. *C. amplificus* is present in both Atlantic and Pacific Ocean samples.

*Size*: 12 to 20 microns.

*Holotype*: USNM 169176 (Pl. 1, figs. 9–10).

*Paratype*: USNM 169177.

*Type locality*: Lamont core V3-153, 531 cm, Atlantic Ocean.

### Ceratolithus primus
Bukry and Percival, n. sp.
Pl. 1, figs. 12–14

*Description*: This small crescent-shaped species is characterized by short arms and very thick arch. In cross-polarized light this form is dark (no birefringence).

*Remarks*: Though possessing the crystallographic orientation of *Ceratolithus tricorniculatus*, this new species is easily distinguished by its lack of long slender arms and by its consistently different overall outline—a broad crescent shape resulting from the dominance of the arch over the arms.

*Occurrence*: *Ceratolithus primus* occurs in upper Miocene marine sediment from the Atlantic and Pacific Oceans. Its stratigraphic range is limited to the lower part of the *Ceratolithus tricorniculatus* Zone, where it occurs slightly lower or in conjunction with *C. tricorniculatus.*

*Size*: 7 to 10 microns.

*Holotype*: USNM 169178 (Pl. 1, fig. 12).

*Paratypes*: USNM 169179 and 169180.

*Type locality*: DSDP core 56.2-1-3, 0–3 cm, Caroline Rise, Pacific Ocean.

## Genus Chiasmolithus Hay, Mohler and Wade, 1966

### Chiasmolithus altus
Bukry and Percival, n. sp.
Pl. 2, figs. 1–2

*Description*: This small elliptic species is characterized by an elliptic to oblong central opening that is spanned by a delicate x-shaped crossbar. Typically the bars meet at 90° angles; on some specimens one set of bars is slightly offset. Measured along the short axis, the central area opening is equal to one third the total width of the coccolith. The rim is composed of about 60 elements and is faint in the outer portion in cross-polarized light.

*Remarks*: *Chiasmolithus altus* is distinguished from the similar species, *Chiasmolithus oamaruensis* (Deflandre) by the smaller central opening and crossbar angles of 90°. *Chiasmolithus oamaruensis* has a central opening equal to one half the coccolith diameter along the short axis and has crossbar angles of approximately 45° and 135° (Pl. 2, fig. 3). *Chiasmolithus solitus* (Bramlette and Sullivan) is about the same size as *C. altus* but has a narrower rim that is bright to the margin in cross-polarized light and the crossbar has one set of bars widely offset (see Bramlette and Sullivan 1961, pl. 2, figs. 4a–4c, and Locker, 1968, pl. 1, figs. 5–6).

*Occurrence*: *Chiasmolithus altus* is known from sediment of late Eocene to early Miocene age. At the beginning of its range in late Eocene and earliest Oligocene *C. altus* occurs with *C. oamaruensis*, but through the remainder of the Oligocene it is the only species of *Chiasmolithus* present and represents the youngest species assigned to the genus.

*Size*: 10 to 18 microns.

*Holotype*: USNM 169181 (Pl. 2, figs. 1–2).

*Type locality*: JOIDES core 6, 39 meters, Blake Plateau, Atlantic Ocean.

## Genus Cyclolithella Loeblich and Tappan, 1963

### Cyclolithella pactilis
Bukry and Percival, n. sp.
Pl. 2, figs. 4–6

*Description*: This small, circular to subcircular species is composed of about 20 moderately imbricate rim elements. The outer margin of the rim cycle is slightly serrate and the margin of the open central area is smooth. The central opening occupies about 40 percent of the coccolith width.

*Remarks*: *Cyclolithella pactilis* is distinguished from *Cyclolithella prionion* (De-

flandre and Fert) by its smaller central opening with respect to rim width and by the smooth inner margin of the rim. It is distinguished from *Cyclolithella inflexa* (Kamptner ex Deflandre) by having about half as many rim elements and by its more circular form.

*Occurrence*: *Cyclolithella pactilis* occurs most commonly in the upper middle Eocene of DSDP Site 19, Leg 3 in the Atlantic Ocean and DSDP Site 44, Leg 6 in the Pacific Ocean.

*Size*: 4 to 6 microns.

*Holotype*: USNM 169183 (Pl. 2, figs. 4–5).

*Paratype*: USNM 169184.

*Type locality*: DSDP core 44-4-2, 145 cm, Horizon Guyot, northwestern Pacific Ocean.

## Genus DICTYOCOCCITES Black, 1967

### DICTYOCOCCITES ABISECTUS (Müller) Bukry and Percival, n. comb.

Pl. 2, figs. 9–11

*Coccolithus* aff. *C. bisectus* (Hay, Mohler and Wade). BRAMLETTE and WILCOXON, 1967, p. 102, pl. 4, figs. 9–10.

*Coccolithus*? *abisectus* MÜLLER, 1970, p. 92, pl. 9, figs. 9–10; pl. 12, fig. 1.

*Remarks*: These large circular to subcircular placoliths have a small circular to subcircular central area surrounded by a thick collar that shows high relief when seen in transmitted light. The broad distal rim is composed of 40 to 60 crystallite elements that are radial or have very slightly counterclockwise inclination. In cross-polarized light, the distal shield is bright and the black extinction lines narrow and dissipate from the periphery towards the center and are disjunct from the lines at the center, inside the central area collar.

*Dictyococcites abisectus* is distinguished from *D. bisectus* by the circular to subcircular shape of the central area, with a small circular opening at the very center, thick collar, and the circular to subcircular rim outline. *D. abisectus* is distinguished from *Cyclococcolithus neogammation* Bramlette and Wilcoxon by its large size, thick collar cycle, and discontinuous extinction lines. Structurally and stratigraphically, *D. abisectus* appears to have been derived from *D. bisectus*.

*Occurrence*: *Dictyococcites abisectus* is rarely present in middle Oligocene *Sphenolithus distentus* Zone assemblages but replaces *D. bisectus* in the upper Oligocene *Sphenolithus ciperoensis* Zone and is most common in this zone and the overlying lower Miocene lower *Triquetrorhabdulus carinatus* Zone. *D. abisectus* is a consistent indicator for this age in the Atlantic and Pacific Oceans, and Cipero Formation of Trinidad.

*Size*: 12 to 16 microns.

*Hypotypes*: USNM 169186 and 169187.

### DICTYOCOCCITES BISECTUS (Hay, Mohler and Wade) Bukry and Percival, n. comb.

Pl. 2, figs. 12–13

*Syracosphaera bisecta* HAY, MOHLER and WADE, 1966, (*partim*), p. 393, pl. 10, figs. 4–6.

*Coccolithus pseudocarteri* HAY, MOHLER and WADE, 1966, (*partim*), p. 385, pl. 2, figs. 2–4.

*Cyclococcolithus dictyodus* (Deflandre and Fert). HAQ, 1966, (*partim*), p. 31, pl. 2, fig. 2; pl. 6, figs. 2 and 6.

*Coccolithus stavensis* LEVIN and JOERGER, 1967, p. 165, pl. 1, figs. 7a–7d.

*Coccolithus bisectus* (Hay, Mohler and Wade). BRAMLETTE and WILCOXON, 1967, p. 102, pl. 4, figs. 11–13.

?*Coccolithus* sp. cf. *C. scissurus* (Hay, Mohler and Wade). BRAMLETTE and WILCOXON, 1967, p. 102, pl. 4, figs. 1–2.

?*Dictyococcites danicus* BLACK, 1967, p. 141, fig. 2.

?*Reticulofenestra dictyoda* (Deflandre and Fert). STRADNER and EDWARDS, 1968, (*partim*), p. 19, pl. 13, figs. 1–2; pl. 14, figs. 2–5.

*Reticulofenestra placomorpha* (Kamptner). STRADNER and EDWARDS, 1968, (*partim*), p. 22, pl. 21, figs. 1–2.

*Stradnerius dictyodus* (Deflandre and Fert). HAQ, 1968, (*partim*), p. 31, pl. 2, figs. 5–8; pl. 3, figs. 1–8.

*Remarks*: This large subcircular placolith has a distal shield that is bright, in cross-polarized light from the center to the peripheral margin. The elliptic central area is slightly concave and extinction lines are obscure here, typically being disjunct from the broad straight extinction lines of the rim. Large specimens have high interference color and a radial line pattern in the central area formed by large lath-shaped crystallites.

*Dictyococcites bisectus* is distinguished from the similar *Dictyococcites scrippsae* by its normally larger size, more nearly circular shape and extinction lines that are broad and nearly straight in the rim but obscure or disjunct in the central area.

*Occurrence*: *Dictyococcites bisectus* has a limited stratigraphic range of upper Eocene to middle Oligocene, but has a wide geographic range in open-ocean and nearshore deposits from areas such as the Gulf Coast of the U.S.A., Europe, and the Atlantic and Pacific Oceans.

*Hypotype*: USNM 169188.

### Dictyococcites scrippsae
Bukry and Percival, n. sp.
Pl. 2, figs. 7–8

*Syracosphaera bisecta* Hay, Mohler and Wade, 1966, (*partim*), p. 393, pl. 10, figs. 1–3.
*Dictyococcites dictyodus* (Deflandre and Fert). Martini, 1969, (*partim*), p. 133, pl. 1, figs. 5–6.

*Description*: These small elliptic placoliths have a solid central area composed of radial calcite laths. In cross-polarized light the extinction lines are continuous from the center to the periphery but bend sharply at the central area border, being distinctly broad and flared in the rim and narrow in the central area.

*Remarks*: *Dictyococcites scrippsae* is distinguished from the similar *Dictyococcites bisectus* by its generally smaller size, more elliptic outline, and continuous, sharply bent extinction lines.

*Occurrence*: *Dictyococcites scrippsae* is a cosmopolitan taxon that occurs abundantly in neritic and open-ocean assemblages ranging from middle Eocene to upper Oligocene.

*Size*: 6 to 12 microns.

*Holotype*: USNM 169185 (Pl. 2, figs. 7–8).

*Type locality*: Red Bluff Clay, Chickasawhay River, Shubuta, Mississippi.

## Genus Discoaster Tan, 1927

### Discoaster bellus
Bukry and Percival, n. sp.
Pl. 3, figs. 1–2

*Description*: These small, simple, five-rayed discoasters lack any central knob or central area development and have straight rays that taper slightly and terminate in points. Rarely a tiny spur is present at the ray points.

*Remarks*: *Discoaster bellus* is distinguished from *Discoaster hamatus* Martini and Bramlette by consistently smaller size and lack of large ray-tip spur. It lacks the delicate non-tapered rays and long bifurcations of *D. pentaradiatus* and the distinctive central knob of other upper Miocene five-rayed discoasters such as *D. berggrenii* and *D. quinqueramus*.

*Occurrence*: *Discoaster bellus* is distinctly smaller and more abundant than *D. hamatus* in oceanic samples (Pacific Ocean, DSDP Leg 6) of the lower upper Miocene (Tortonian) *Discoaster hamatus* Zone and persists above *D. hamatus* into the overlying *Discoaster neohamatus* Zone.

*Size*: 8 to 14 microns.

*Holotype*: USNM 169189 (Pl. 3, fig. 1).

*Paratypes*: USNM 169190 and 169191.

*Type locality*: DSDP core 55.0-4-1, 130–131 cm, Caroline Rise, Pacific Ocean.

### Discoaster mohleri
Bukry and Percival, n. sp.
Pl. 3, figs. 3–5

*Discoaster gemmeus* Stradner. Hay and Mohler, 1967, p. 1538, pl. 204, figs. 19–21; pl. 205, figs. 1–3; pl. 206, figs. 3, 5–6, 8.

*Description*: This discoaster is composed of 9 to 16 radial straight rays that have essentially no separation and terminate in broad points. There is a slight depression at the center and no central knob structure. The inter-ray sutures are depressed below the general level of the rays that have a median ridge.

*Remarks*: Excellent electronmicrographs of this new species have been published by Hay and Mohler (1967). A combination of the characters of small to moderate size, straight rays with median ridge, no free-ray length and lack of central knob distinguish *Discoaster mohleri* from other early Tertiary multiray discoaster species such as *D. lubinaensis* Bystricka, *D. multiradiatus* Bramlette and Riedel, *D. nobilis* Martini, and *D. ornatus* Stradner. Although the first description of *D. gemmeus* Stradner was attributed to a Paleocene occurrence (Stradner, 1959; Hay and Mohler, 1967), other species reported by Stradner to occur in the same "Paleocene sample" included *D. barbadiensis* Tan, *D. distinctus* Martini, *D. lodoensis* Bramlette and Riedel, *D. mirus* Deflandre, *D. rotans* Stradner, and *D. tribrachiatus* Bramlette and Riedel, now known to be lower or middle Eocene taxa. Stradner and Papp (1961) illus-

trated *D. gemmeus* from the middle Eocene (Lutetian) of Austria. The occurrence of *D. gemmeus* as originally figured has been noted in middle Eocene assemblages from oceanic cores where there is no evidence of reworking, as in the Lamont-Doherty core A-150-1, 92 cm, and the Deep Sea Drilling Project core 44-3-5, 145–150 cm. The rays of *D. gemmeus* imbricate more than those of *Discoaster mohleri.* Therefore, the much larger species having more rays, better developed pointed ray terminations and less central thickening than *D. gemmeus* is named *Discoaster mohleri. Discoaster mohleri* is common in many upper Paleocene samples and is the first discoaster.

*Occurrence*: *Discoaster mohleri* first occurs in the upper Paleocene *Heliolithus riedeli* Zone and is extinct by the end of the Paleocene. It is a cosmopolitan species present in deep-ocean cores from the Atlantic and Pacific Oceans and from land outcrops in France and Trinidad.

*Size*: 8 to 16 microns.

*Holotype*: USNM 169192 (Pl. 3, fig. 3).

*Paratypes*: USNM 169193 and 169194.

*Type locality*: DSDP core 47.2-9-6, 0–5 cm, Shatsky Rise, Pacific Ocean.

### Discoaster prepentaradiatus
Bukry and Percival, n. sp.
Pl. 3, figs. 6–7

*Description*: This small symmetric five-rayed discoaster has no central area developed and has thin bifurcations at the ray tips. The bifurcate tips and rays lie in the same plane.

*Remarks*: *Discoaster prepentaradiatus* is basically comparable to *D. pentaradiatus* Tan but lacks the typical strongly downward bent rays of that species. Further, *D. prepentaradiatus* is distinguished from *D. asymmetricus* Gartner and *D. moorei* Bukry by being symmetric and is distinguished from *D. berggrenii* Bukry, *D. bellus* Bukry and Percival, and *D. quinqueramus* Gartner by having equant bifurcations at the tips of the rays.

*Occurrence*: *Discoaster prepentaradiatus* occurs in lower upper Miocene marine sediments from the Atlantic and Pacific Oceans.

*Size*: 9 to 12 microns.

*Holotype*: USNM 169195 (Pl. 3, fig. 6).

*Paratype*: USNM 169196.

*Type locality*: DSDP core 55.0-5-5, 126–127 cm, Caroline Rise, Pacific Ocean.

### Discoaster variabilis pansus
Bukry and Percival, n. subsp.
Pl. 3, figs. 8–9

*Discoaster* aff. *D. variabilis* Martini and Bramlette, 1963, pl. 104, fig. 9.

*Description*: This large six-rayed discoaster has tapering rays that terminate in large broadly bifurcate tips. The large bifurcate limbs are almost perpendicular to the rays. There is a small central knob in the medium-sized central area.

*Remarks*: *Discoaster variabilis pansus* is distinguished from *D. variabilis decorus* Bukry, which has very long tapering rays terminating in very narrow, small bifurcations, by its wide large bifurcations nearly perpendicular to the moderately long rays. *Discoaster variabilis variabilis* Martini and Bramlette is considered to be the main stock, having more moderately sized and angled bifurcations between the two end members, *D. variabilis decorus* and *D. variabilis pansus. Discoaster challengeri* Bramlette and Riedel is six-rayed and has terminal bifurcations but is readily distinguished from *D. variabilis pansus* by having parallel-sided rays and no central area development.

*Occurrence*: *Discoaster variabilis pansus* occurs in upper Miocene and lower Pliocene marine sediments equivalent to the *Ceratolithus tricorniculatus* Zone, *Ceratolithus rugosus* Zone, and *Reticulofenestra pseudoumbilica* Zone in cores from the Atlantic and Pacific Oceans. Its first occurrence is after that of *D. variabilis variabilis* and before *D. variabilis decorus.*

*Size*: 15 to 25 microns.

*Holotype*: USNM 169197 (Pl. 3, fig. 8).

*Paratype*: USNM 169198.

*Type locality*: DSDP core 47.2-6-3, 114 cm, Shatsky Rise, Pacific Ocean.

## Genus Discoasteroides Bramlette and Sullivan, 1961

### Discoasteroides bramlettei
Bukry and Percival, n. sp.
Pl. 3, figs. 10–12

*Description*: This species is circular in plan view with a serrate outline and a main cycle composed of 17 to 21 straight, radial elements that are not in contact only at the broadly pointed tips forming the serrate margin. This main cycle of elements is dark

in cross-polarized light. A smaller secondary cycle of 17 to 22 straight radial elements forms a central structure that rises slightly above the level of the main cycle and is bright in cross-polarized light with an extinction cross.

*Remarks*: The main cycle with recessed sutures, a high ridge on each element, and each element ending in a blunt point are characters similar to those of early species of *Discoaster.* But the small central cycle that is bright in cross-polarized light and occupies one half to one quarter of the diameter of the main cycle distinguishes *Discoasteroides bramlettei* from species of *Discoaster. Discoasteroides bramlettei* is distinguished from *Discoasteroides kuepperi* (Stradner) by having more than twice as many elements in each cycle and a much more closely appressed secondary cycle. It is distinguished from *Discoasteroides megastypus* Bramlette and Sullivan by having a prominent outer cycle with fewer rays and a serrate margin to the inner cycle rather than a high stem.

*Occurrence*: *Discoasteroides bramlettei* is common in samples of the upper Paleocene *Heliolithus kleinpelli* Zone of the Shatsky Rise in the northwestern Pacific Ocean at the type locality. This species has also been observed in samples of upper Paleocene sediment from Belus, France (M. N. Bramlette, personal commun., 1969).

*Size*: 9 to 11 microns.

*Holotype*: USNM 169200 (Pl. 3, figs. 11–12).

*Paratype*: USNM 169199.

*Type locality*: DSDP core 47.2-9-5, 77–78 cm, Shatsky Rise, Pacific Ocean.

## Genus DISCOLITHINA Loeblich and Tappan, 1963

### DISCOLITHINA LATOCULATA Bukry and Percival, n. sp. Pl. 4, figs. 1–3

*Description*: This large species is strongly elliptic (eccentricity: 1.3 to 1.5) and has a narrow unornamented rim. The central plate has vague concentric substructure and an elliptic central opening aligned with the long axis of the discolith. In cross-polarized light, the central opening appears larger when oriented 45° to the polarization directions than when oriented parallel to polarization directions owing to convergence of the extinction lines at the ends of the central opening in that position.

*Remarks*: The central opening and lack of ornamentation or crossbar distinguishes *Discolithina latoculata* from most other discolith taxa. The taxon most similar to *D. latoculata* is *Discolithina rimosa* (Bramlette and Sullivan); it is distinguished from *D. latoculata* by its great thickness and by lacking a distinct rim cycle. Though these differences could result from differential preservation, they probably represent evolutionary development, since *D. latoculata* occurs later than the latest occurrence of *D. rimosa.*

*Occurrence*: *Discolithina latoculata* occurs in the upper Eocene Yazoo Clay and lower Oligocene Red Bluff Clay of the Gulf Coast region of the United States.

*Size*: 12 to 16 microns.

*Holotype*: USNM 169201 (Pl. 4, figs. 1–3).

*Type locality*: Shubuta Member of the Yazoo Clay, Chickasawhay River, Shubuta, Mississippi.

### DISCOLITHINA SEGMENTA Bukry and Percival, n. sp. Pl. 4, figs. 4–6

*Description*: This imperforate elliptic species is constructed of approximately 30 radially arrayed elements that extend from the long axis of the discolith. The interelement sutures are recessed along their length, giving the surface of the discolith a corrugated appearance and the peripheral margin a scalloped appearance. In cross-polarized light the extinction gyres are simply defined along the elements from the periphery to the central axis.

*Remarks*: No other species of *Discolithina* lacking a rim cycle has the typical corrugated solid surface that results from the simple construction of *Discolithina segmenta.* Other species of imperforate discoliths such as *Discolithina japonica* Takayama or *Discolithina plana* (Bramlette and Sullivan) have a smooth peripheral margin and no large constructional elements evident in light microscopy. *Discolithina ovata* Levin and Joerger lacks a rim but is distinguished by having fewer elements and two median sig-

moidal slits. *Discolithina segmenta* probably developed from *D. ovata*, a lower Oligocene species.

*Occurrence*: Though occurring only in small numbers, *Discolithina segmenta* is often recognized in deep-ocean samples of late Oligocene sediment from the Atlantic and Pacific Oceans. It occurs in the late Oligocene strata of the Cipero Formation of Trinidad.

*Size*: 8 to 12 microns.

*Holotype*: USNM 169202 (Pl. 4, figs. 4–5).

*Paratype*: USNM 169203.

*Type locality*: JOIDES core 2, 100 meters, Blake Plateau, Atlantic Ocean.

## Genus Ellipsolithus Sullivan, 1964

### Ellipsolithus lajollaensis
Bukry and Percival, n. sp.
Pl. 4, figs. 7–8

*Description*: This elongate species is characterized by rounded ends and long parallel sides of the rim and central area. The rim cycle is composed of about 35 to 40 radial elements. The central area, occupying less than a third of the coccolith width contains two rows of perforations. Each row is composed of 5 to 8 perforations. When examined with only one polarizer of the microscope, the entire coccolith—rim and central area—is in strong relief (medium refraction index 1.518) when the long axis is oriented parallel to the polarization direction; the relief is very weak when the long axis is perpendicular to the polarization direction. In cross-polarized light, and oriented parallel to a polarization direction, the extinction lines developed in the rim of the long coccolith sides are very weak and diffused and the central area structure is dark. At a 45° orientation the central area and rim is bright and extinction lines are narrowly defined at the rounded ends of the coccolith.

*Remarks*: *Ellipsolithus lajollaensis* is distinguished from the similarly constructed *Ellipsolithus distichus* (Bramlette and Sullivan) by having two parallel sides instead of an elliptic outline, a central area occupying less than a third of the coccolith width instead of more than a third, a greater number of perforations, a less prominent central rib, and fewer rim elements—35 to 40 instead of 50 to 60 (Hay and Mohler, 1967).

*Occurrence*: *Ellipsolithus lajollaensis* occurs sparsely in the lower middle Eocene Rose Canyon Shale of Hanna (1926) at La Jolla, California and in the Donzacq Marl, Donzacq, France.

*Size*: 8 to 12 microns.

*Holotype*: USNM 169204 (Pl. 4, figs. 7–8).

*Type locality*: Rose Canyon Shale of Hanna (1926); seacliff at Salk Institute, La Jolla, California.

## Genus Fasciculithus Bramlette and Sullivan, 1961

### Fasciculithus magnus
Bukry and Percival, n. sp.
Pl. 4, figs. 9–12

*Description*: This large species is characterized by a very deep concave depression at one end and by a distinctive narrowing of the cylindric body about halfway towards the other end. The body of the cylinder is solid, composed of about 20 high wedge-shaped elements. In side view, the outline slopes in toward the central axis from the larger portion of the cylinder (where the conical depression is) to the narrow part of the cylinder.

*Remarks*: *Fasciculithus magnus* is distinguished from *Fasciculithus schaubi* Hay and Mohler by lacking six concave sides and pit-and-ridge ornamentation. *Fasciculithus magnus* is distinguished from *Fasciculithus involutus* Bramlette and Sullivan and *Fasciculithus tympaniformis* by having a distinctive change in cylinder diameter half way along its length and by having a very deep conical depression at one end.

*Occurrence*: *Fasciculithus magnus* is common in the lower Paleocene carbonate ooze of the Shatsky Rise in the northwestern Pacific Ocean.

*Size*: 10 to 17 microns.

*Holotype*: USNM 169205 (Pl. 4, figs. 9–10).

*Paratypes*: USNM 169206 and 169207.

*Type locality*: DSDP core 47.2-10-5, 109–110 cm, Shatsky Rise, Pacific Ocean.

Genus HELICOPONTOSPHAERA Hay and Mohler, 1967

HELICOPONTOSPHAERA GRANULATA Bukry and Percival, n. sp.
Pl. 5, figs. 1–2

*Description*: This elongate species with helicoid rim has an oblong-shaped central area. In bright-field illumination the central area appears granular, probably owing to the presence of a field of equidimensional crystallites. In cross-polarized light the central part of the central area is brighter than the ends.

*Remarks*: *Helicopontosphaera granulata* superficially resembles *Helicopontosphaera kamptneri* Hay and Mohler in lacking bars or large perforations in the elliptic to oblong central area. *Helicopontosphaera granulata* is distinguished from *H. kamptneri* by having a central-area structure that lacks the regularly aligned lath-shaped crystallites and median slit or suture. Thus in cross-polarized light the faint and granular pattern of the central area of *Helicopontosphaera granulata* is distinct from the bright field with median slit shown by *H. kamptneri.*

*Occurrence*: *Helicopontosphaera granulata* is most common in lower middle Miocene assemblages of the *Sphenolithus heteromorphus* Zone and *Discoaster exilis* Zone and persists through the upper Miocene in Deep Sea Drilling Project cores from the Atlantic (Leg 3) and Pacific (Leg 6) Oceans.

*Size*: 10 to 12 microns.

*Holotype*: USNM 169208 (Pl. 5, figs. 1–2).

*Type locality*: DSDP core 15-3-2, 78–79 cm, Mid-Atlantic Ridge, Atlantic Ocean.

Genus LOPHODOLITHUS Deflandre, 1954

LOPHODOLITHUS ACUTUS Bukry and Percival, n. sp.
Pl. 5, figs. 3–5

*Description*: This broadly elliptic species has a narrow rim which is expanded into a flange on one side and one end, producing an asymmetric form. The large central area is open except for a single crossbar that spans the central opening in approximate alignment with the short axis of the elliptic outline. The narrow side and end of the rim meet at a distinctive right angle or slightly acute angle that contrasts the broadly rounded rim at the diagonally opposite position on the rim.

*Remarks*: The distinctive thinning of the rim toward one end with one limb almost a straight line, and the right angle or acute angle at one position in the rim distinguish *Lophodolithus acutus* from similar species such as *Lophodolithus mochlophorus* Deflandre, *Lophodolithus nascens* Bramlette and Sullivan, and *Lophodolithus rotundus* Bukry and Percival, all of which have broadly oval, bilaterally symmetric rims.

*Occurrence*: *Lophodolithus acutus* is known from the middle Eocene Aragon Formation of Mexico and has been observed

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PLATE 1
Magnification 2000×

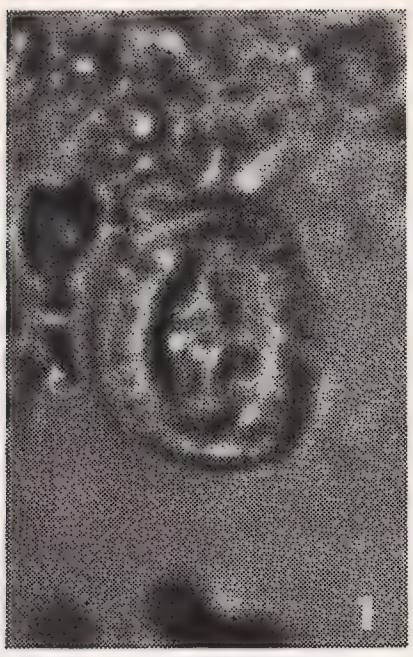
Figures — Page

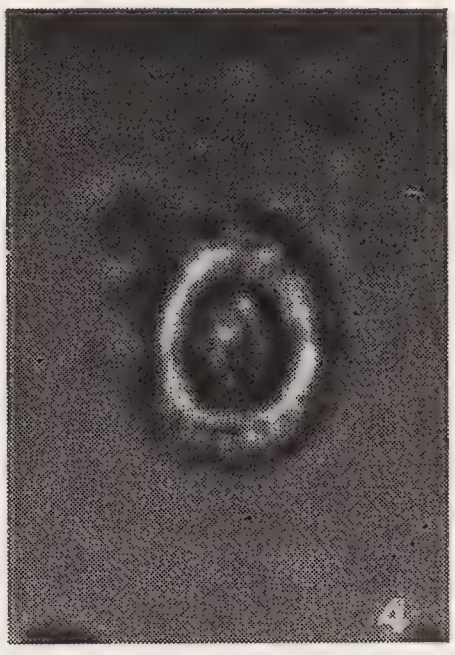
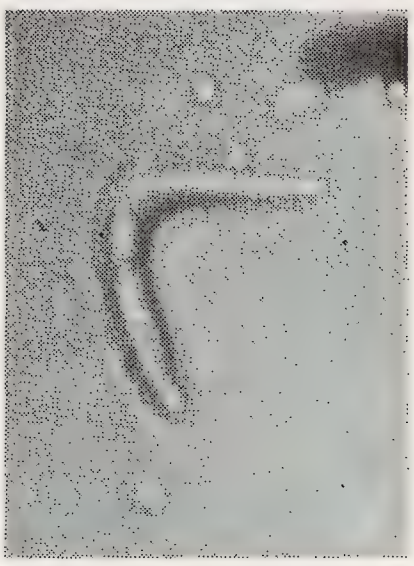
1–4 *Campylosphaera eodela* Bukry and Percival, n. sp. ---- 125
(1) holotype USNM 169171, J4, 87 meters; (2) cross-polarized; (3) J4, 84 meters, phase-contrast, USNM 169172; (4) J4, 83 meters, USNM 169173.

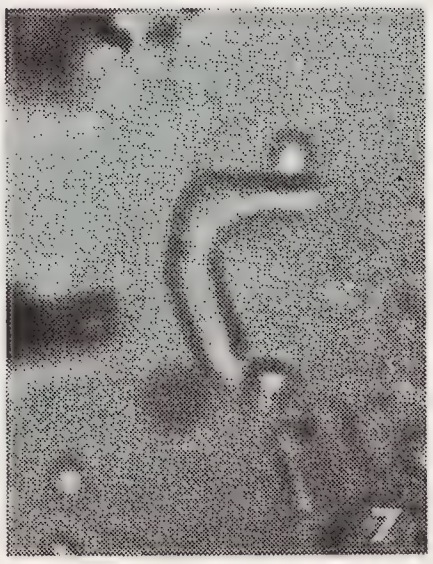
5–8 *Ceratolithina? vesca* Bukry and Percival, n. sp. ---- 125
(5) holotype USNM 169174, Hospital Hill Marl; (6) cross-polarized; (7) USNM 169175; (8) cross-polarized.

9–11 *Ceratolithus amplificus* Bukry and Percival, n. sp. ---- 125
(9) holotype USNM 169176, V3-153, 531 cm; (10) cross-polarized; (11) USNM 169177.

12–14 *Ceratolithus primus* Bukry and Percival, n. sp. ---- 126
(12) holotype USNM 169178, 56.2-1-3, 0–3 cm; (13) 56.2-1-4, 130–131 cm, USNM 169179; (14) 56.2-1-3, 0–3 cm, USNM 169180.





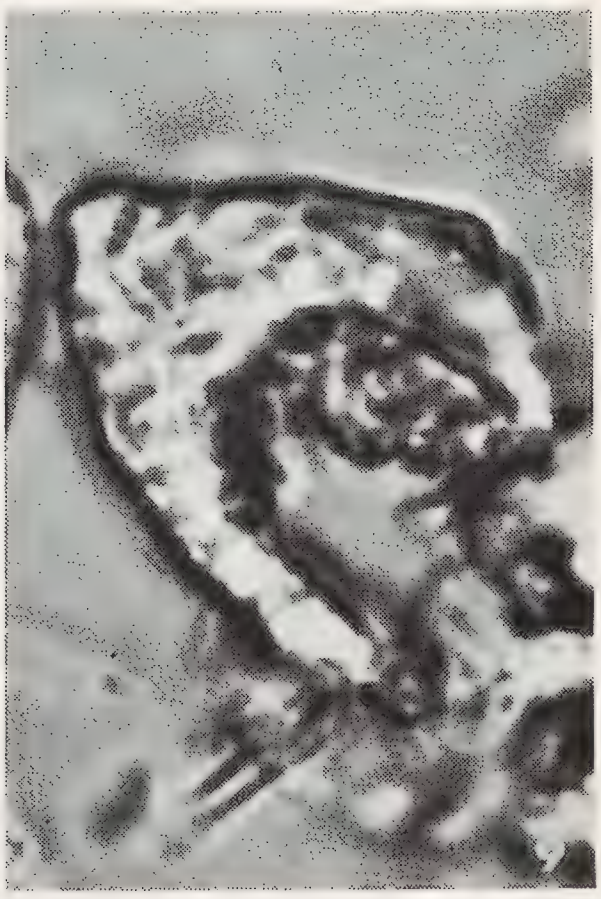
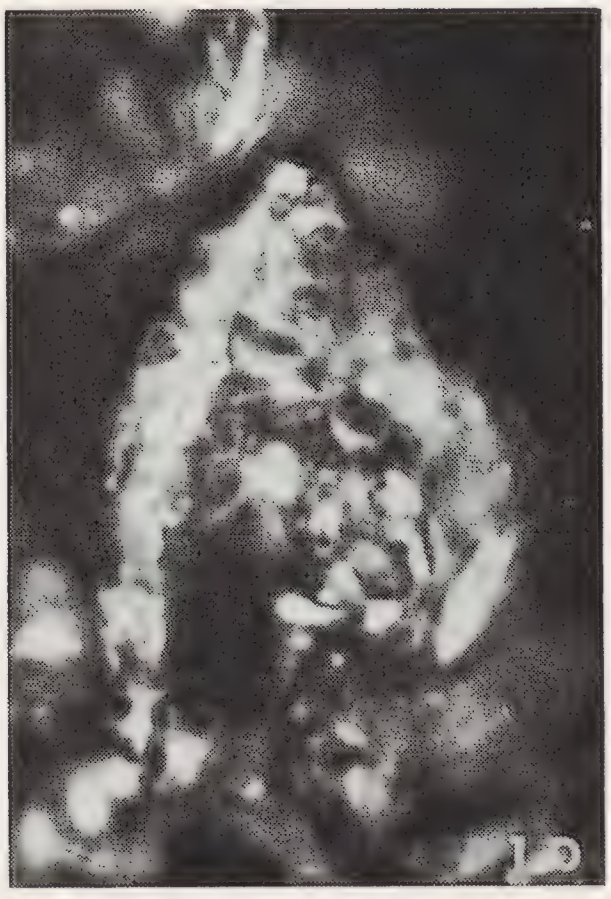
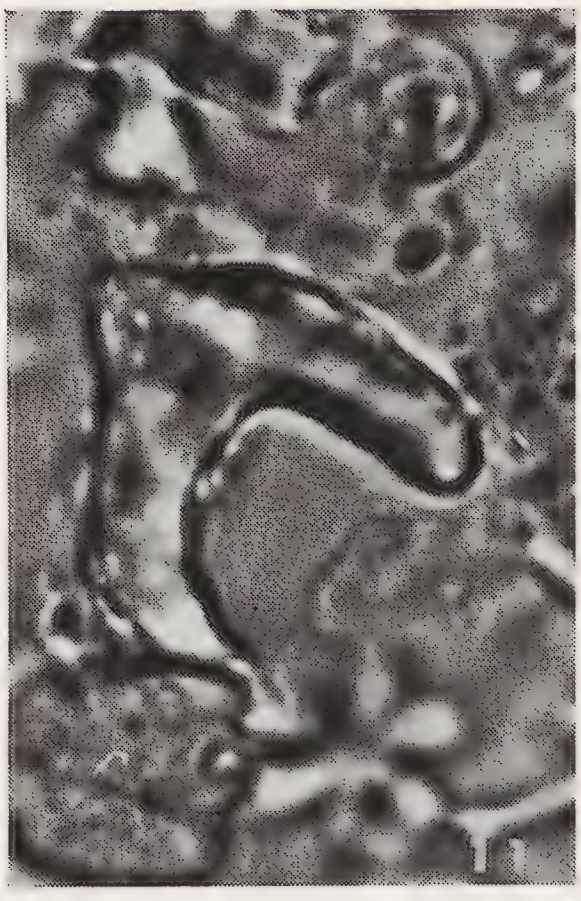




PLATE 1

from the middle Eocene of California (M. N. Bramlette, personal communication, 1970).

*Size*: 10 to 12 microns.

*Holotype*: USNM 169209 (Pl. 5, figs. 3–4).

*Paratype*: USNM 169210.

*Type locality*: Formación Aragón, type locality, El Rio la Puerta, west-southwest of La Antiqua, Mexico.

LOPHODOLITHUS ROTUNDUS
Bukry and Percival, n. sp.
Pl. 5, figs. 6–7

*Description*: This large species is bilaterally symmetric along the long axis but has an asymmetric enlargement of the flange such that the main subcircular body of the coccolith occupies only half of the total length and covers only one end of the coccolith. The asymmetric rim flange is composed of 50 to 70 straight, essentially radial elements. The outline of the rim flange is oblong to subelliptic and in cross-polarized light the extinction gyres in the rim have slight counterclockwise inclination in proximal view. The central area wall is prominent but there is no distinctive structure observed within the central area.

*Remarks*: *Lophodolithus rotundus* is distinguished from the similar species *Lophodolithus mochlophorus* Deflandre by the subcircular symmetric shape of the central area and by the lack of any central area crossbar structure or vestige.

*Occurrence*: *Lophodolithus rotundus* is present in a marine core sample from the South Pacific that contains other coccoliths of middle Eocene age.

*Size*: 16 to 23 microns.

*Holotype*: 169211 (Pl. 5, figs. 6–7).

*Type locality*: Scripps core DWBG-23B, core catcher sample, Pacific Ocean.

Genus MICRANTHOLITHUS Deflandre, 1954

MICRANTHOLITHUS ARTICULATUS, n. sp.
Bukry and Percival
Pl. 5, figs. 8–11

*Description*: This large symmetric species has five long slender rays with medial sutures. The outer half of the rays is unusually terminated, the medial sutures disappearing at a slight node then reappearing at the tip as the dividing line between two unequal segments. This arrangement may be the result of one segment of the ray passing under the other and reappearing at the tip.

*Remarks*: *Micrantholithus articulatus* is distinguished from other long, slender-rayed species such as *Micrantholithus attenuatus* Bramlette and Sullivan by the unique ar-

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PLATE 2
Magnification 2000×

Figures

1–2 *Chiasmolithus altus* Bukry and Percival, n. sp. ---- 126
(1) holotype USNM 169181, J6, 39 meters; (2) cross-polarized.

3 *Chiasmolithus oamaruensis* (Deflandre) ---- 126
(3) Oamaru Diatomite, USNM 169182.

4–6 *Cyclolithella pactilis* Bukry and Percival, n. sp. ---- 126
(4) holotype USNM 169183, 44-4-2, 145 cm; (5) cross-polarized, (6) USNM 169184, cross-polarized.

7–8 *Dictyococcites scrippsae* Bukry and Percival, n. sp. ---- 128
(7) holotype, USNM 169185, Shubuta Member of Yazoo Clay; (8) cross-polarized.

9–11 *Dictyococcites abisectus* (Müller) Bukry and Percival, n. comb. ---- 127
(9) 55.0-13-1, 120–121 cm, USNM 169186; (10) cross-polarized; (11) USNM 169187, cross-polarized.

12–13 *Dictyococcites bisectus* (Hay, Mohler and Wade) Bukry and Percival, n. comb. 127
(12) Red Bluff Clay, USNM 169188; (13) cross-polarized.

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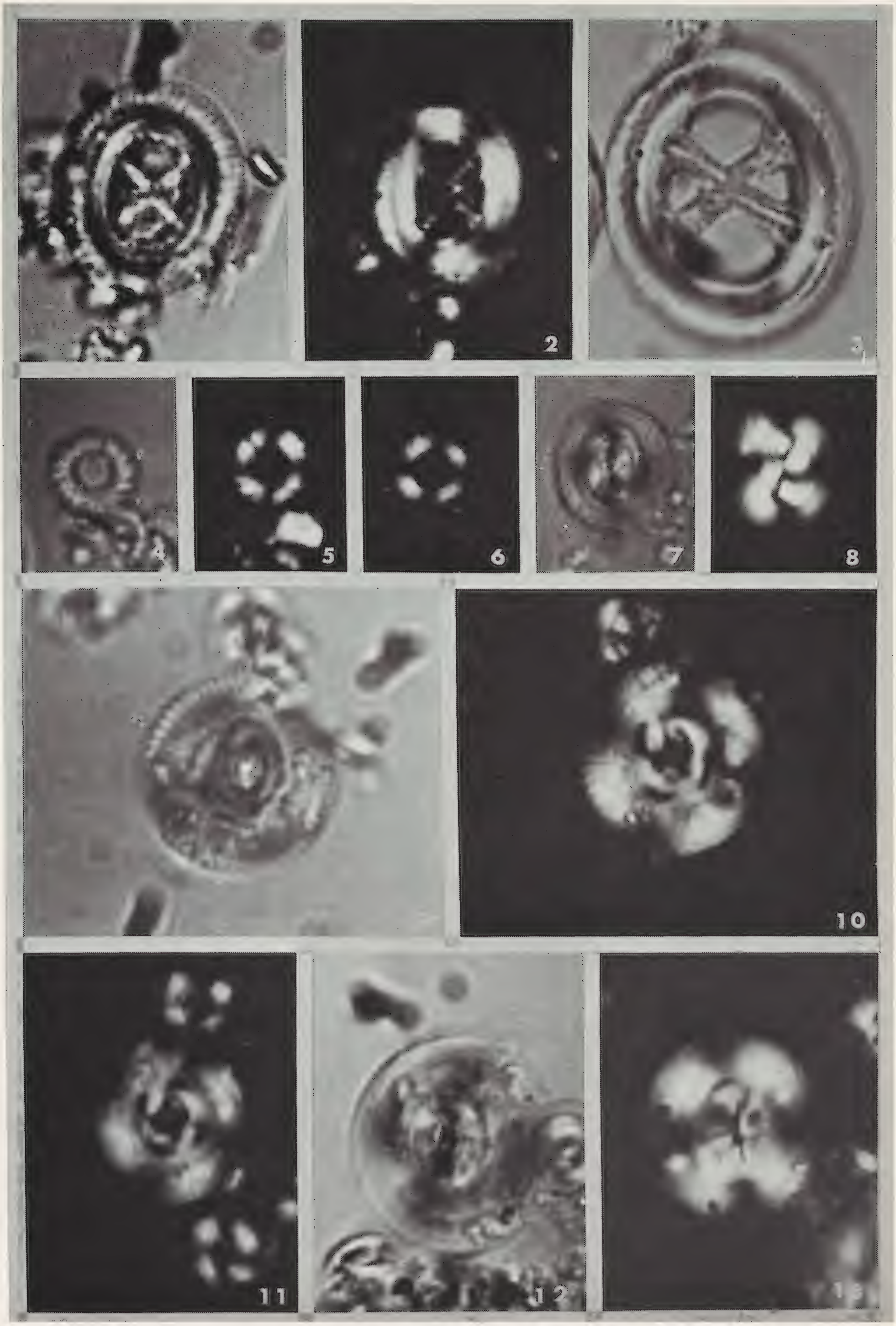


PLATE 2

rangement of the outer part of the ray segments which appear to cross over. No other species of *Micrantholithus* have such construction.

*Occurrence*: *Micrantholithus articulatus* is known only from the upper Eocene of the southwestern U.S.S.R. at Nal'chik in the Caucasus. Associated nannofossils from this locality have been described by Hay, Mohler and Wade (1966).

*Size*: 20 to 30 microns.

*Holotype*: USNM 169212 (Pl. 5, figs. 8–9).

*Paratypes*: USNM 169213 and 169214.

*Type locality*: Nal'chik, Caucasus, U.S.S.R.; Nal'chik-11.

## Reticulofenestra samodurovi (Hay, Mohler and Wade), n. comb.

*Apertapetra samodurovi* Hay, Mohler and Wade, 1966, p. 388, pl. 6, figs. 1–7.

*Remarks*: The structure of the rim and collar cycles and the cross-polarized light image of this species matches that of species of *Reticulofenestra*. *Reticulofenestra samodurovi* is distinguished by its smaller size and stratigraphically lower first occurrence than other species of the genus.

## Reticulofenestra hillae Bukry and Percival, n. sp. Pl. 6, figs. 1–3

?*Discolithus* ?*cuvillieri* Lezaud, 1968 (*partim*), p. 22, pl. 1, figs. 1–2.

*Description*: This large elliptic placolith has a thick, wide elliptic collar around a small central area opening that occupies less than a third of placolith length.

*Remarks*: *Reticulofenestra hillae* is distinguished from *Reticulofenestra umbilica* (Levin) by its more prominent, wider central area collar and by the correspondingly smaller central opening. It is distinguished from *Dictyococcites abisectus* by its elliptic shape and larger central opening.

*Occurrence*: *Reticulofenestra hillae* commonly occurs with *R. umbilica* in the upper Eocene and lower Oligocene, namely in the later part of the range of *R. umbilica*. It is most common in the lower Oligocene. Geographically it is present in sediments from the Atlantic and Pacific Oceans, the Gulf Coast of the United States and Europe.

*Size*: 14 to 20 microns.

*Holotype*: USNM 169215 (Pl. 6, figs. 1–2).

*Paratype*: USNM 169216.

*Type locality*: Shubuta Member of Yazoo Clay, Chickasawhay River, Shubuta, Mississippi.

## Reticulofenestra umbilica (Levin)

*Coccolithus umbilicus* Levin, 1965, p. 265, pl. 41, fig. 2.

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## Plate 3

Magnification 2000×, unless noted otherwise


Figures — Page

1–2 *Discoaster bellus* Bukry and Percival, n. sp. ---- 128
(1) holotype USNM 169189, 55.0-4-1, 130–131 cm; (2) USNM 169190 and 169191.

3–5 *Discoaster mohleri* Bukry and Percival, n. sp. ---- 128
(3) holotype USNM 169192, 47.2-9-6, 0–5 cm; (4) USNM 169193; (5) USNM 169194.

6–7 *Discoaster prepentaradiatus* Bukry and Percival, n. sp. ---- 129
(6) holotype USNM 169195, 55.0-5-5, 126–127 cm; (7) USNM 169196.

8–9 *Discoaster variabilis pansus* Bukry and Percival, n. subsp. ---- 129
(8) holotype USNM 169197, 47.2-6-3, 114 cm; (9) USNM 169198.

10–12 *Discoasteroides bramlettei* Bukry and Percival, n. sp. ---- 129
(10) 47.2-9-5, 77–78 cm, USNM 169199, electronmicrograph, 2500×; (11) holotype USNM 169200; (12) cross-polarized.

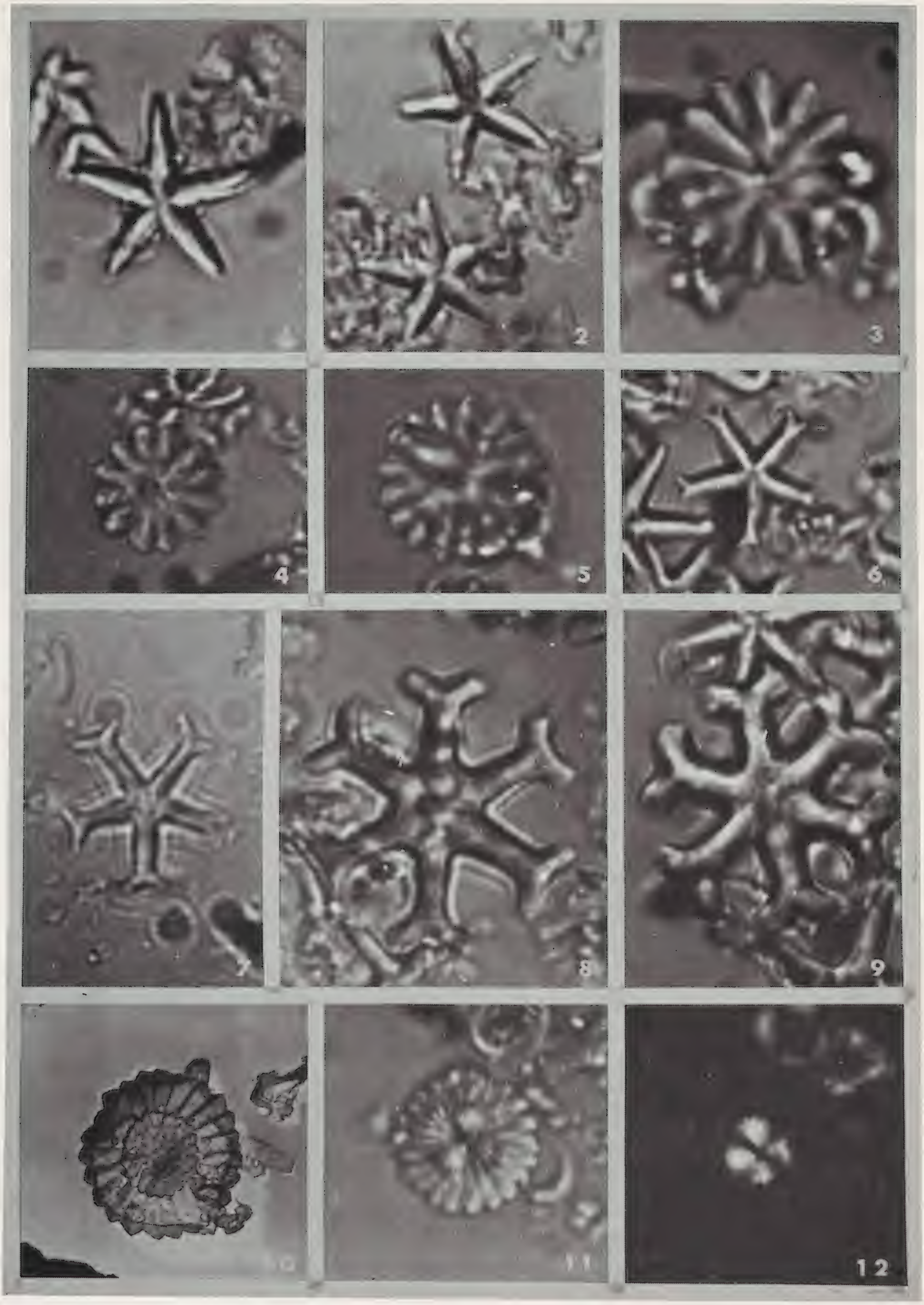


PLATE 3

*Reticulofenestra caucasica* Hay, Mohler and Wade, 1966 (*partim*), p. 386, pl. 3, figs. 1–2; pl. 4, figs. 1–2.
*Reticulofenestra umbilica* (Levin). Martini and Ritzkowski, 1968, p. 245, pl. 1, figs. 11–12.

*Remarks*: The most common and long-ranging of the varieties of *Reticulofenestra umbilica* (Levin) has a large central opening occupying from a third to a half of the coccolith length. The central area is surrounded by a bright narrow collar (in cross-polarized light), and well-preserved specimens have a reticulate structure in the central area.

*Occurrence*: *Reticulofenestra umbilica* apparently developed from a smaller, more circular species, *Reticulofenestra samodurovi* (Hay, Mohler and Wade) during the middle Eocene. The large specimens of *R. umbilica* first occur in upper middle Eocene sediments and persist as an abundant cosmopolitan member of coccolith assemblages into the lower Oligocene.

Genus Scyphosphaera Lohmann, 1902

Scyphosphaera expansa
Bukry and Percival, n. sp.
Pl. 6, figs. 10–13

*Description*: This simple, tall conical-shaped species has thin, high, straight walls that extend from the base at an angle of approximately 100° such that the diameter of the central opening gradually increases from the base to the open top. The exterior of the wall has the regular sculpture typical of *Scyphosphaera* and the wall terminates simply at the open end. The height of the wall is variable from about 18 to 36 microns, whereas the diameter of the base is consistently about 9 microns and the wall-to-base angle is consistently about 100°, so the open end always has a larger diameter than the base.

*Remarks*: *Scyphosphaera expansa* differs from other species of *Scyphosphaera* by having straight walls that terminate simply and are inclined such that the end is larger than the closed base. The only other species with largely outwardly inclined walls, *Scyphosphaera apsteinii* Lohmann var. *recta* Deflandre and *Scyphosphaera recurvata* Deflandre, have walls that are distinctly curved inward near the top.

*Occurrence*: *Scyphosphaera expansa* is one of the earliest scyphosphaerids. It is sparsely present in the lower middle Eocene sediment of the Aragon Formation of Mexico.

*Size*: 18 to 36 microns.

*Holotype*: USNM 169224 (Pl. 6, figs. 12–13).

*Paratypes*: USNM 169222 and 169223.

*Type locality*: Formación Aragón, type locality, El Rio la Puerta, west-southwest of La Antiqua, Mexico.

Scyphosphaera globulata
Bukry and Percival, n. sp.
Pl. 7, figs. 1–6

*Description*: In profile, this small species has curved walls that rise from a small base

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Plate 4
Magnification 2000×

Figures — Page

1–3 *Discolithina latoculata* Bukry and Percival, n. sp. ---- 130
(1) holotype USNM 169201, Shubuta Member of Yazoo Clay; (2) cross-polarized, 0° to polarizer; (3) 45° to polarizer.

4–6 *Discolithina segmenta* Bukry and Percival, n. sp. ---- 130
(4) holotype USNM 169202, J2, 100 meters; (5) cross-polarized, 45° to polarizer; (6) USNM 169203, 55-7-5, 80 cm, cross-polarized, 0° to polarizer.

7–8 *Ellipsolithus lajollaensis* Bukry and Percival, n. sp. ---- 131
(7) holotype USNM 169204, Rose Canyon Shale of Hanna (1926); (8) cross-polarized, 45° to polarizer.

9–12 *Fasciculithus magnus* Bukry and Percival, n. sp. ---- 131
(9) holotype USNM 169205, 47.2-10-5, 109–110 cm; (10) cross-polarized; (11) USNM 169206, top view; (12) USNM 169207, surface.

PLATE 4

and almost close at a small apical opening. The profile is almost circular and the surface of the globular form is characterized by longitudinal ribs (10 to 15 visible in side view). As in many species of *Scyphosphaera*, these longitudinal ribs have regularly spaced nodes giving rise to a reticulate appearance with the longitudinal ribs dominant.

*Remarks*: *Scyphosphaera globulata* is distinguished from other species of *Scyphosphaera* by its almost spherical shape and very small apical opening. The most similar species, *Scyphosphaera apsteinii* Lohmann, is somewhat elliptic in profile and has a much larger apical opening.

*Occurrence*: This species is most common in warm-water oceanic deposits of late Miocene age but may occur less frequently in early Pliocene deposits.

*Size*: 10 to 17 microns.

*Holotype*: USNM 169225 (Pl. 7, figs. 1–2).

*Paratypes*: USNM 169226 to 169228.

*Type locality*: Texas A and M core 64-A-9-5E, 150 cm, Gulf of Mexico. Sample from T. E. Pyle.

## Genus Sphenolithus Deflandre, 1952

### Sphenolithus capricornutus
Bukry and Percival, n. sp.
Pl. 6, figs. 4–6

*Description*: This species has two prominent tapering, diverging spines and a comparatively short base. The lower part of the spines is broad and is separated along the central axis of the sphenolith at a distance above the base that is equivalent to the height of the base.

*Remarks*: *Sphenolithus capricornutus* is distinguished from *Sphenolithus furcatolithoides* Locker by a greater degree of divergence between the two spines and by divergence at a point much closer to the basal cycle.

*Occurrence*: *Sphenolithus capricornutus* is commonly present in upper Oligocene to lower Miocene samples from the South Atlantic Ocean (DSDP Leg 3, Site 14).

*Size*: 6 to 10 microns.

*Holotype*: USNM 169217 (Pl. 6, figs. 4–5).

*Paratype*: USNM 169218.

*Type locality*: DSDP core 14-2-1, 72–73 cm, Mid-Atlantic Ridge, Atlantic Ocean.

### Sphenolithus dissimilis
Bukry and Percival, n. sp.
Pl. 6, figs. 7–9

*Description*: This small species is characterized by the three-part arrangement of its apical spine-like crystallites. The basal area of the sphenolith is usually wider than the upper portion. The basal portion, when observed in cross-polarized light, shows two kinds of crystallite orientation: a lower cycle of spines inclined to the central axis of the nannofossil and above it a set of spines arranged perpendicular to the axis (Pl. 6, fig. 7). The upper portion of the sphenolith has a group of appressed spines parallel or subparallel to the central axis. Commonly, about three spines are visible, in side view.

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## Plate 5
Magnification 2000×

Figures — Page

1–2 *Helicopontosphaera granulata* Bukry and Percival, n. sp. ---- 132
(1) holotype USNM 169208, 15-3-2, 78–79 cm; (2) cross-polarized.

3–5 *Lophodolithus acutus* Bukry and Percival, n. sp. ---- 132
(3) holotype USNM 169209, type Formación Aragón; (4) cross-polarized; (5) USNM 169210, cross-polarized.

6–7 *Lophodolithus rotundus* Bukry and Percival, n. sp. ---- 134
(6) holotype USNM 169211, DWBG-23B, core catcher; (7) cross-polarized.

8–11 *Micrantholithus articulatus* Bukry and Percival, n. sp. ---- 134
(8) holotype USNM 169212, Nal'chik-11; (9) cross-polarized; (10) USNM 169213; (11) USNM 169214, cross-polarized.

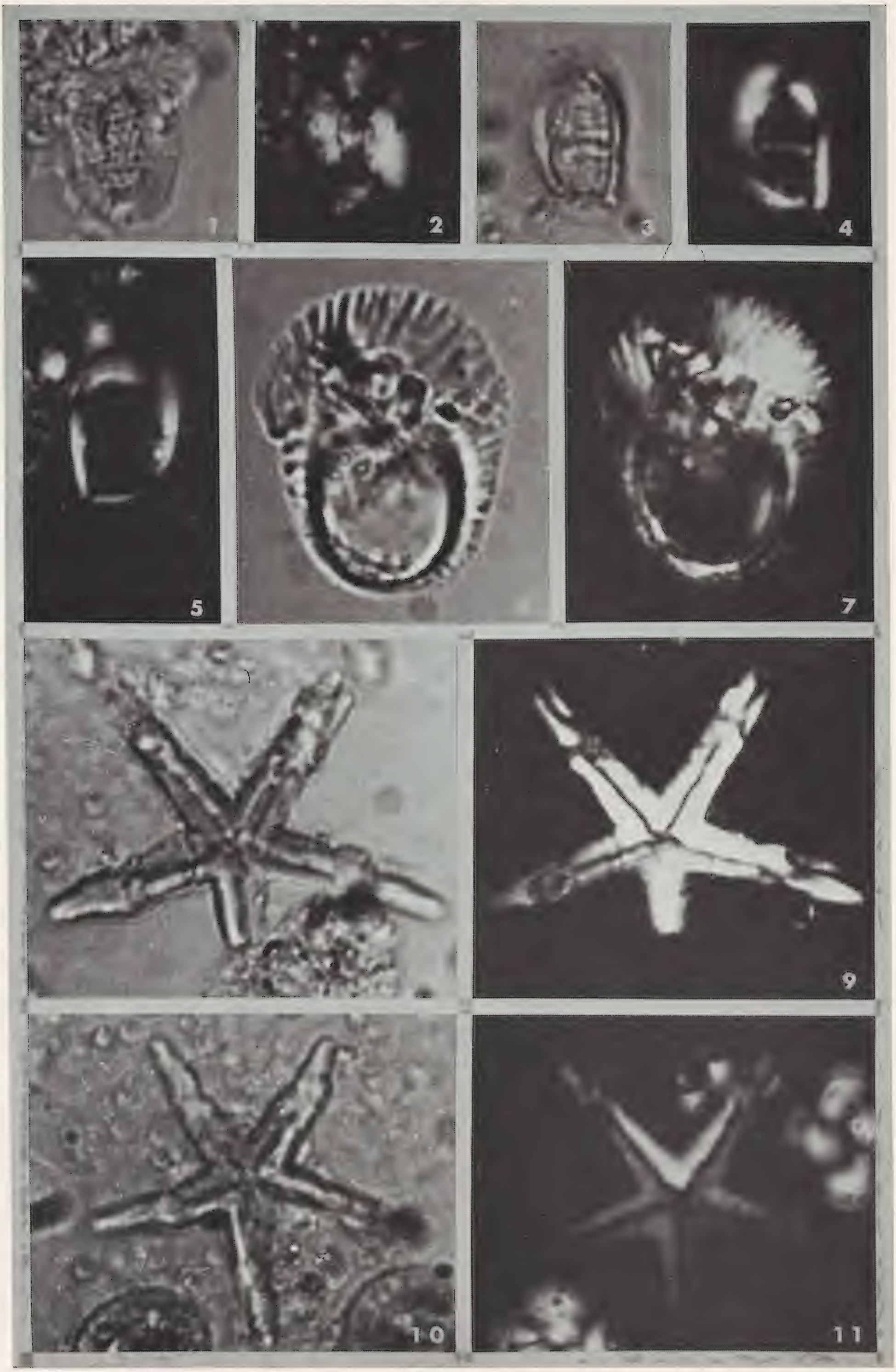


PLATE 5

*Remarks*: *Sphenolithus dissimilis* is distinguished from the somewhat similar *Sphenolithus abies* Deflandre and *Sphenolithus moriformis* (Brönnimann and Stradner) by having a clearly defined basal and upper portion of about equivalent height and an upper portion that is dominated by about three spines all parallel or subparallel to the central axis.

*Occurrence*: *Sphenolithus dissimilis* is abundant in late Oligocene and early Miocene marine carbonate ooze from Atlantic Ocean regions: Blake Plateau JOIDES cores, Cipero Formation of Trinidad, DSDP Leg 3 cores; and the northwestern Pacific: DSDP Leg 6 cores.

*Size*: 5 to 10 microns.

*Holotype*: USNM 169219 (Pl. 6, fig. 7).

*Paratypes*: USNM 169220 and 169221.

*Type locality*: Cipero Formation, Trinidad (T.L.L. 206, 264; Bo. 287), *Catapsydrax dissimilis* Zone of Bolli (1957a).

## Genus Syracosphaera Lohmann, 1902

### Syracosphaera? wechesensis Bukry and Percival, n. sp.
Pl. 7, figs. 7–10

*Description*: This elliptic, high-walled species has a large elliptic central opening. The inside of the wall has a regularly spaced series of ridges. The ends of these ridges form a cycle of beads at the base of the wall, where there is a narrow inner flange. A narrow indistinct outer flange is sometimes present at the wider end of the wall cycle, but most specimens lack a flange.

*Remarks*: *Syracosphaera? wechesensis* is distinguished from other similar species such as *Syracosphaera labrosa* Bukry and Bramlette by having a distinctive cycle of wall ridges that appear at the juncture of the wall and small basal flange as a cycle of beads and a well-defined central opening, and by lacking a broad outer rim flange. *Transversopontis pulcher* (Deflandre) has a similar cycle of beads but is distinguished by having a broad crossbar in the central area and a broader inner flange.

*Occurrence*: *Syracosphaera? wechesensis* is common in certain lower middle Eocene deposits of the Weches Formation at San Augustine, Texas, and from the Caucasus region of the U.S.S.R. This species has not yet been recognized in marine sediment cores.

*Size*: 10 to 15 microns.

*Holotype*: USNM 169229 (Pl. 7, figs. 7–8).

*Paratype*: USNM 169230.

*Type locality*: Weches Formation, Roberts School, San Augustine, Texas.

## Genera Incertae Sedis

### Genus Vermiculithina Bukry and Percival, n. gen.

*Description*: This genus includes calcareous nannofossils that are cylindrical and

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## Plate 6

Magnification 2000×, unless noted otherwise

Figures — Page

1–3 *Reticulofenestra hillae* Bukry and Percival, n. sp. ---- 136
(1) holotype USNM 169215, Shubuta Member of Yazoo Clay; (2) cross-polarized; (3) USNM 169216.

4–6 *Sphenolithus capricornutus* Bukry and Percival, n. sp. ---- 140
(4) holotype USNM 169217, 14-2-1, 72–73 cm; (5) cross-polarized, 0° to polarizer; (6) USNM 169218, 14-2-2, 73–74 cm, cross-polarized.

7–9 *Sphenolithus dissimilis* Bukry and Percival, n. sp. ---- 140
(7) holotype USNM 169219, Cipero Formation, cross-polarized, 45° to polarizer; (8) USNM 169220, J2, 100 meters, cross-polarized, 45° to polarizer; (9) USNM 169221, Cipero Formation.

10–13 *Scyphosphaera expansa* Bukry and Percival, n. sp. ---- 138
(10) USNM 169222, type Formación Aragón, 1000×; (11) USNM 169223, 1000×; (12) holotype USNM 169224, 1000×; (13) cross-polarized.

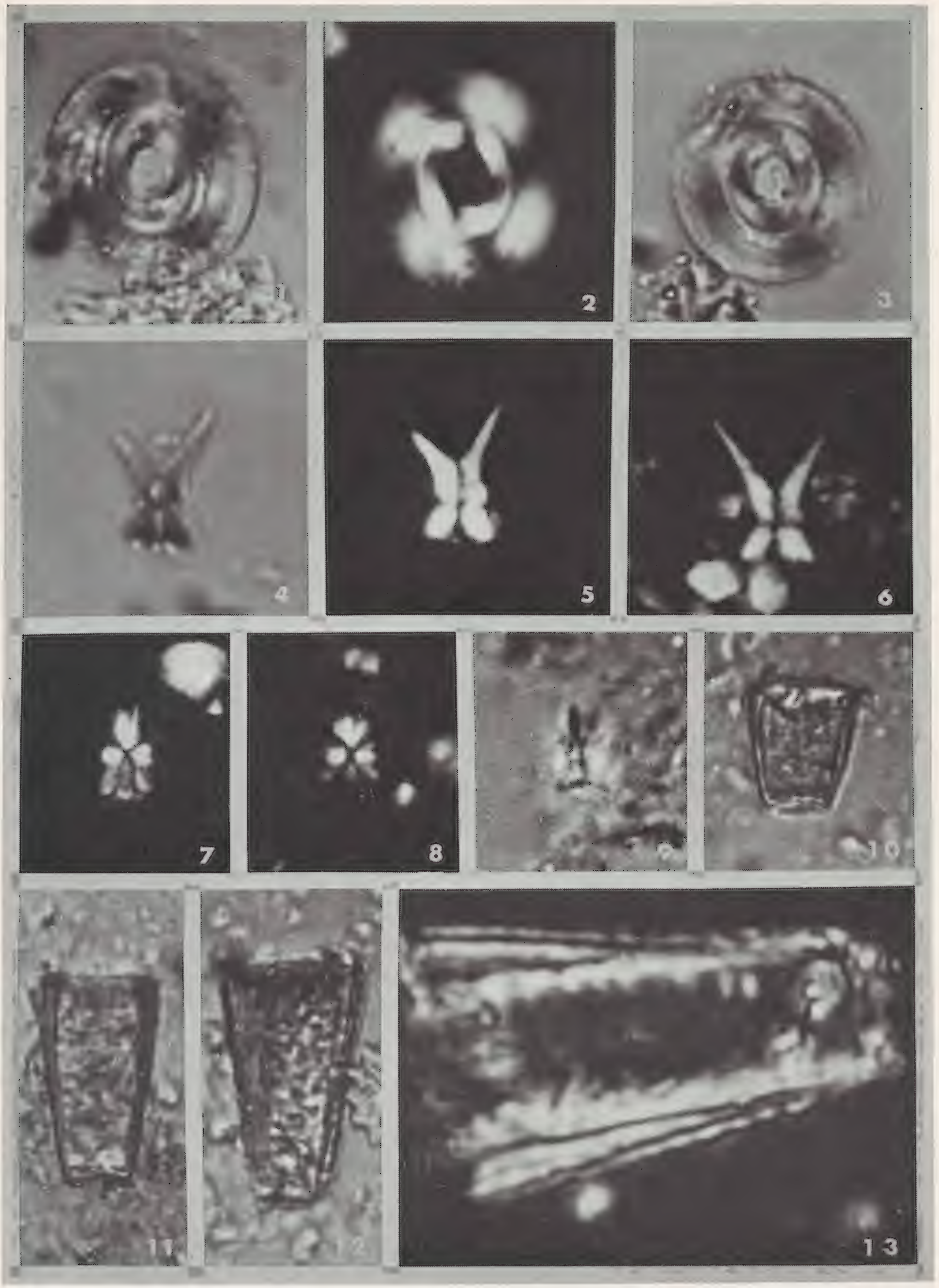


PLATE 6

taper slightly such that the ends are narrower than the middle part. There is a narrow central canal and the curving cylindrical wall is constructed of innumerable crystallites.

*Type species*: *Vermiculithina arca*, n. sp.

*Remarks*: Other genera of calcareous nannofossils that may have elongate shapes and be constructed of large numbers of very small elements such as *Thoracosphaera* Kamptner and *Nannoconus* Kamptner are never curved in the distinctive manner of *Vermiculithina.*

### Vermiculithina arca
Bukry and Percival, n. gen., n. sp.
Pl. 7, fig. 11

*Description*: This species is a large, curved, cylindrical form that tapers towards the two smaller ends of the cylinder. A narrow central canal, occupying a third or less of the cylinder diameter, extends the entire length of the cylinder. The curvature of the cylinder consistently forms a semicircle. Innumerable radially arrayed tiny elements form the structure.

*Remarks*: The large doubly tapering cylinder in a semicircular shape is unlike any other species or genus of calcareous nannofossil. Though the outward shape and size somewhat resembles a sponge spicule, the complex ultrastructure of *Vermiculithina arca* suggests a fossil nannoplankton origin.

*Occurrence*: *Vermiculithina arca* is present in small numbers in lower Oligocene nannofossil ooze from the Blake Plateau in the Atlantic Ocean east of Florida (JOIDES core 3).

*Size*: 50 to 70 microns.

*Holotype*: USNM 169231 (Pl. 7, fig. 11).

*Type locality*: JOIDES core 3, 130 meters, Blake Plateau, Atlantic Ocean.

## IV. Samples

*Pacific Ocean region*

DSDP core 44 (19°19′N., 169°00′W.).
DSDP core 47.2 (32°27′N., 157°43′E.).
DSDP core 55.0 (09°18′N., 142°33′E.).
DSDP core 56.2 (08°22′N., 143°34′E.).
DSDP core 57.1 (08°41′N., 143°32′E.).
Scripps core DWBG-23B (16°42′S., 145° 48′W.).
La Jolla Formation, Rose Canyon Shale Member, La Jolla, California.
Oamaru Diatomite, Jacksons Paddock, New Zealand.

*Atlantic Ocean region*

DSDP core 14 (28°20′S., 20°56′W.).
DSDP core 15 (30°53′S., 17°59′W.).
JOIDES core 2 (30°20′N., 80°20′W.).
JOIDES core 3 (21°30′N., 77°31′W.).
JOIDES core 4 (31°02′N., 77°43′W.).
JOIDES core 6 (30°05′N., 79°15′W.).
Lamont core V3-153 (28°24′N., 77°56′ W.).
Cipero Formation, Trinidad, T.L.L. 206, 262; Bo. 285 and T.L.L. 206, 264; Bo. 287.
Navet Formation, Hospital Hill Marl, Trinidad (T.L.L. 238, 622; Bo. 536).

*Europe*

Nal'chik Marl, sample 11, Nal'chik, Caucasus, U.S.S.R.

*Gulf Coast region*

Texas A and M core 64-A-9-5E (23°50′N., 92°24′W.).

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### Plate 7
Magnification 2000×, unless noted otherwise


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|---|---|---|
| 1–6 | *Scyphosphaera globulata* Bukry and Percival, n. sp. (1) holotype USNM 169225, 64-A-9-5E, 180 cm; (2) phase-contrast; (3) USNM 169226; (4) cross-polarized; (5) USNM 169227, 57.1-1-3, 68 cm, cross-polarized, top view; (6) USNM 169228, cross-polarized. | 138 |
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| 11 | *Vermiculithina arca* Bukry and Percival, n. sp., n. gen. (11) holotype USNM 169231, J3, 130 meters, 1000×. | 144 |

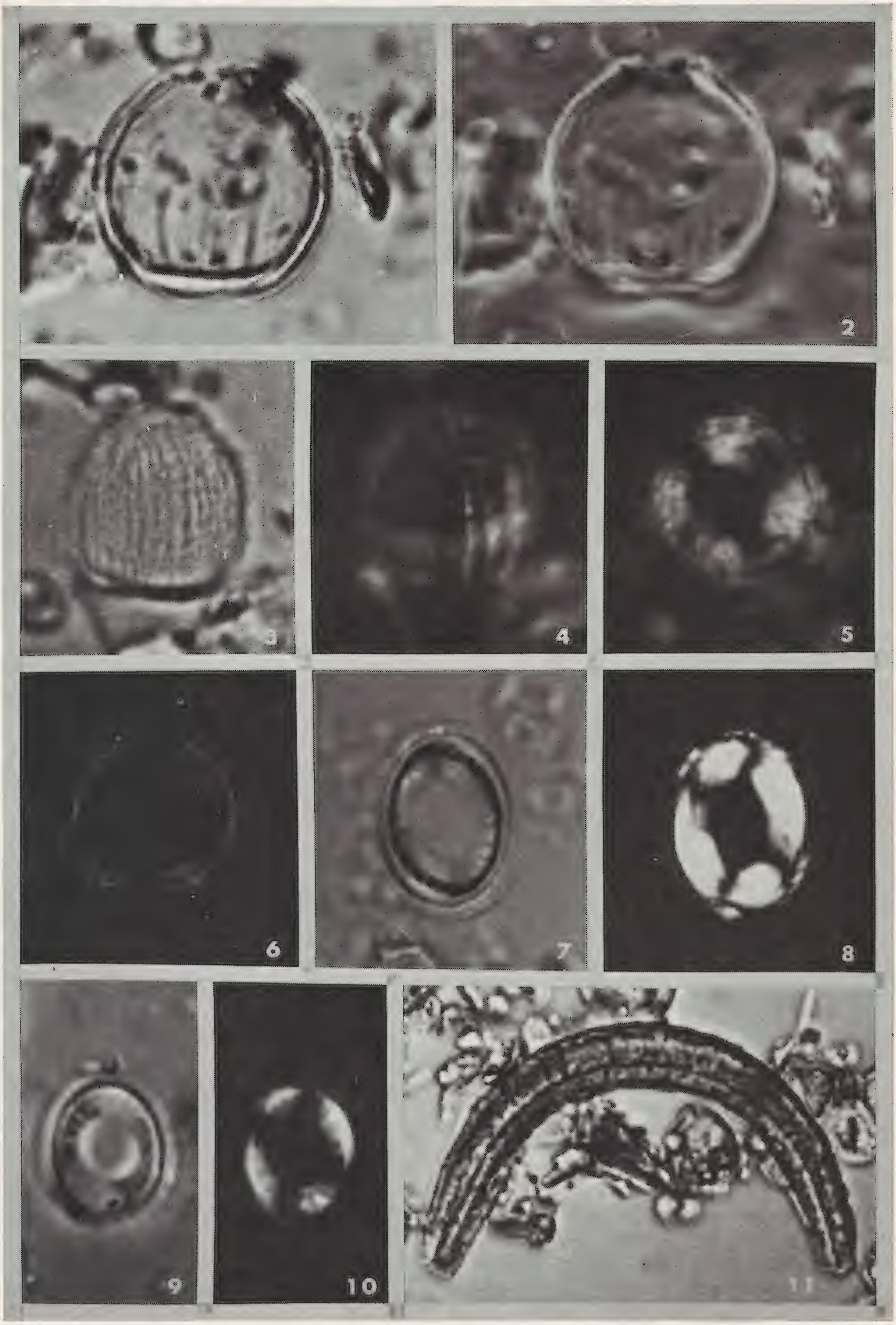


PLATE 7

Cook Mountain Formation, Columbus Landing, Sabine Parish, Louisiana.

Formación Aragón, type locality, El Rio la Puerta, west-southwest of La Antiqua, Mexico.

Red Bluff Clay, Chickasawhay River, Shubuta, Mississippi.

Weches Formation, Roberts School, San Augustine, Texas.

Shubuta Member of Yazoo Clay, Chickasawhay River, Shubuta, Mississippi.

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April 12, 1971

## RECENT BOOK

HUNTING FOR DINOSAURS, by Zofia Kielan-Jaworowska, translated from the Polish by the Israel Translation Society. Published by The MIT Press, Cambridge, Massachusetts, and London, England, 1970, xiv + 177 pp., illus., $7.95

This book describes the adventures of the woman leader of three paleontological expeditions organized by the Warsaw Academy of Sciences to collect fossil dinosaurs in the Gobi Desert. The text is entertaining, informative, and reveals the hardships that confront the field paleontologist even in these times. It is well illustrated by numerous and excellent photographs.

# ESTUARINE FORAMINIFERAL ASSOCIATIONS OF THE BEAUFORT AREA, NORTH CAROLINA

W. H. AKERS
*CHEVRON OIL COMPANY, NEW ORLEANS*

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## I. Abstract

An inventory of foraminifera in the Beaufort area shows that patterns of distribution are similar to those of other estuarine environments. The known geographic ranges of several species reported previously from Trinidad and the northern Gulf of Mexico are extended northward to the Beaufort area. Living foraminifera were found at low tide in an intertidal marsh among the roots of *Spartina alterniflora* in moist mud of the upper few centimeters down to 35–40 centimeters below the marsh surface. A new species of *Miliammina* is described from the surface sediments of this marsh.

## II. Introduction

### A. *The Area*

The study area extends from the continental shelf into Beaufort Inlet, up Core Creek to Adams Creek, and into the Neuse River. The Newport River between Core Creek and Newport, North Carolina, is included in order that faunal changes along a complete salinity gradient may be observed. General types of environments sampled include the inner sublittoral zone of the continental shelf, *Spartina* marshes, mud flats, sand flats, the littoral zone of sand beaches, and fluvial-marine channels. Collecting stations are shown in Figure 1. General en-

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vironmental conditions and seasonal fluctuations of temperature and salinity are described for the Beaufort area by Pearse *et al.* (1942) and Stephenson and Stephenson (1952).

### B. *The Problem*

Objectives were threefold: first, to investigate the pattern of foraminiferal associations in the subject area; second, to inventory the species as to living and post-mortem components of the assemblages; and third, to determine whether foraminifera live at depths below the sediment surface in intertidal estuarine environments comparable to depths reported for sublittoral areas.

### C. *Previous Work*

The living foraminiferal meiofauna of the intertidal zone has been long neglected except for certain perennially subaqueous environments such as swamps, stream channels, and tidal pools, the general assumption among foraminiferalogists being that uninterrupted submergence is necessary for survival. Boltovskoy (1966) has already reviewed the meager literature on survival at various depths in sediments from subtidal areas, and in his own research he has found 16 centimeters to be the maximum depth at which specimens containing protoplasm occurred below the sediment surface at three localities in Chile. The number of species and individuals was observed to increase with decrease in depth, and this vertical penetration was thought to be related to aeration, although Boltovskoy emphasized that oxygen requirements might actually be less than generally believed.

Little previous work has been done on foraminifera in the Beaufort area. Hadley (1936) listed 23 species from a beach locality and two dredgings in the neritic zone near Beaufort. His investigation was not of an ecologic nature, and protoplasm tests were not conducted. *Asterigerina* and *Quinqueloculina* were reported from sand beaches at Beaufort (Pearse *et al.,* 1942), but no distinction was made as to whether specimens were living or dead. It is not unlikely that the tests were reworked from nearby formations of Yorktown or Waccamaw age. (Fossil *Amphistegina lessonii* was found by the present writer in supralittoral sands on Bogue Banks, near Morehead City, North Carolina.) Miller (1953) listed 42 species from nine stations in Mason Inlet, North Carolina, most of which were sublittoral. Tests for the presence of protoplasm were not conducted, and salinity was estimated by taste. Substratum conditions were concluded to control the distribution of foraminifera within the inlet. Farther removed from the study area, Nichols and Ellison (1967) subdivided the Rappahannock Estuary, northeastern Virginia, into three microfaunal biofacies: river, shoal, and basin. They evaluated the ratio method (living specimens to total tests) of estimating relative rates of sedimentation.

### D. *Procedure*

Approximately 80 cubic centimeters of material was collected at the sediment surface from each station. Additional samples were taken below the sediment surface at selected stations by either manual insertion of a plastic core-liner that was marked off vertically in centimeters (inside diameter, 5.7 centimeters) or by excavation by means of a spade with direct measurement of the depth. Channel and continental shelf samplings were recovered by dredge and grab devices on board the "Beveridge", 55-foot trawler of Duke University Marine Laboratory. Water depth was recorded by fathometer; temperature, by reversing thermometer; and salinity, by hydrometer. Other environmental factors noted are recorded in the station descriptions to follow. Samples were prepared with hexamethyleneamine buffered formaldehyde and, prior to examination, immersed in a solution of Rose Bengal to stain the protoplasm of specimens alive at the time of sampling, as recommended by Walton (1952). Each sample was wet-sieved on a U. S. Standard Sieve Series no. 180 screen (openings of 83 microns), dried, and examined for the microfauna. Both stained and unstained foraminifera were transferred from the residues to slides for identification. Relative numbers of species and individuals were estimated during observation of the assemblages, and this method was regarded to be as significant and accurate for the purposes of the present survey as sophisticated statistical calculations, such as "foraminiferal numbers" or counts derived by aliquot splits for a cubic centimeter of sediment. In this report, "rare" is

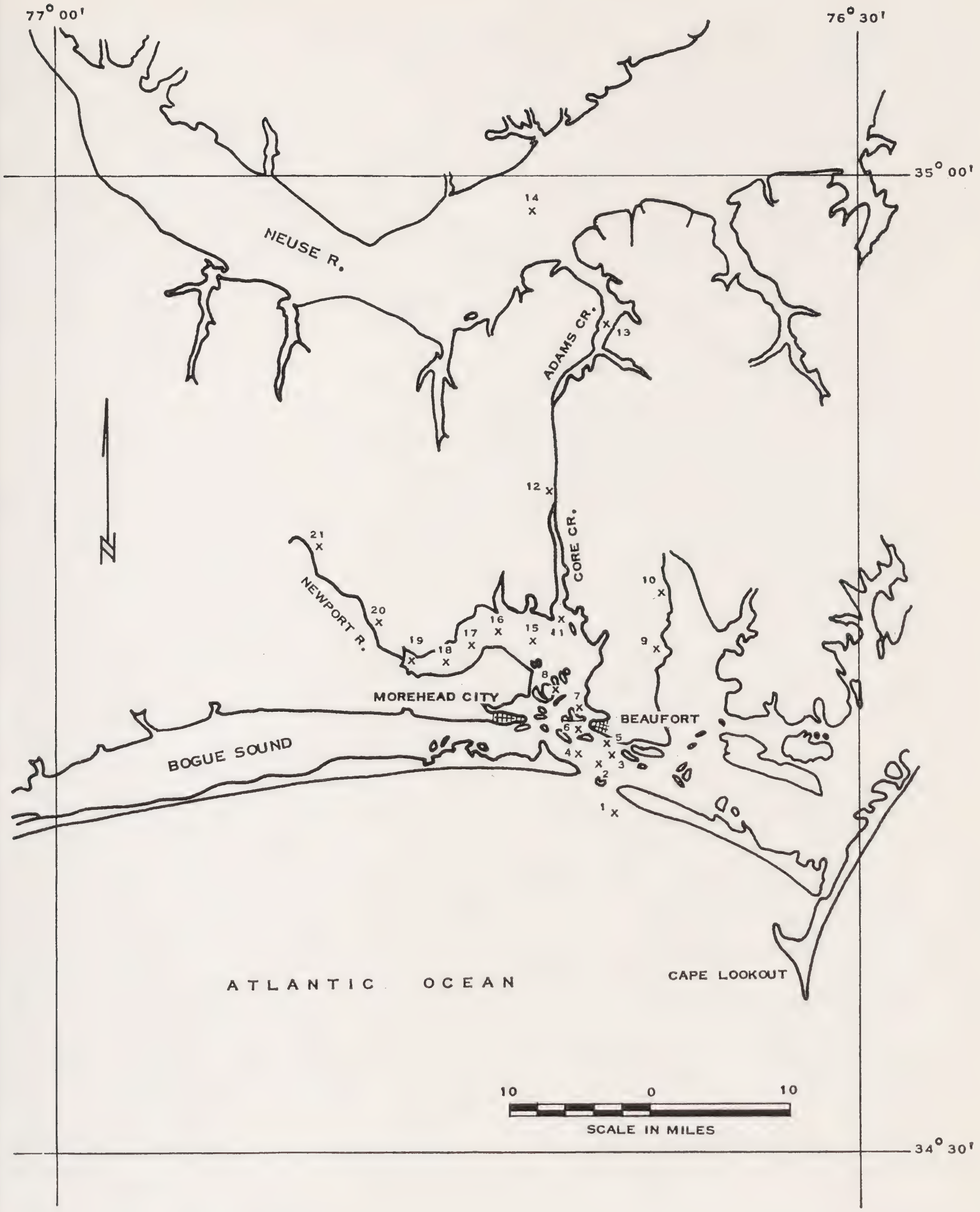


FIGURE 1. COLLECTING STATIONS, BEAUFORT AREA, NORTH CAROLINA

FROM U. S. DEPT. OF COMMERCE COAST AND GEODETIC SURVEY, CAPE HATTERAS TO CHARLESTON, C. AND G. S. 1110. SCALE: 1:432,720 AT LAT. 34 DEGREES.

used for a single individual, "occasional" for two or three, "frequent" for four to ten, and "abundant" for eleven or more. This system is adequate for comparison of the assemblages, because a standard sample size was used for the examinations. The most abundant estuarine species (stations 8A–21) are illustrated with Stereoscan photographs.

### E. *Acknowledgments*

Opportunity to investigate various environments of an estuarine area for foraminiferal associations was afforded at Duke University Marine Laboratory, Beaufort, North Carolina, by NSF grant number GB-7443. Guidance in field and laboratory work during the summer of 1969 by Dr. Patrick Boaden, Queens University, Belfast, Northern Ireland, and Mr. William W. Kirby-Smith, Duke University, is gratefully acknowledged. Dr. H. V. Andersen made the Warren (1957) collection at Louisiana State University available to the writer. Mr. C. W. Poag, Chevron Oil Company, assisted in collection and preparation of some of the material and was a source of suggestions throughout the project. Mrs. Louisa MacLaren assisted in searching the samples for foraminifera.

## III. Foraminiferal Communities at the Sediment Surface (With Post-Mortem Components)

### *Station 1 (Continental Shelf)*

A dredge sample was included from this locality in order to relate the assemblage to foraminiferal associations found in the nearby estuarine environments. Station 1 was in the open Atlantic Ocean, and the depth of water was 11 meters. Foraminiferal distribution off the southern Atlantic Coast has been reviewed by Wilcoxon (1964). Species noted in abundance at this station are the following:

*Ammonia beccarii* (Linné)
*Elphidium gunteri* Cole
*Hanzawia concentrica* (Cushman)
*Quinqueloculina seminulum* (Linné)

The following species were frequent:

*Cibicides pseudoungerianus* (Cushman)
*Elphidium incertum* (Williamson) variant
*Florilus atlanticus* (Cushman)
*Globigerinoides ruber* (d'Orbigny)
*Quinqueloculina poeyana* d'Orbigny

Occasional species were:

*Buccella hannai* (Phleger and Parker)
*Quinqueloculina compta* Cushman
*Quinqueloculina* spp.
*Trochammina* sp.

The following species were rare:

*Globigerina bulloides* d'Orbigny
*Hastigerina (Hastigerina) siphonifera siphonifera* (d'Orbigny)
*Poroeponides cribrorepandus* Asano and Uchio
*Orbulina universa* d'Orbigny

Only two species were alive at this station when the sample was taken. These were *Elphidium gunteri* Cole (abundant) and *Elphidium incertum* (Williamson) variant (occasional).

### *Station 2 (Beaufort Inlet)*

The residue at this locality was mainly medium to coarse quartz sand with abundant broken and polished mollusk shells. Only *Elphidium gunteri* Cole was abundant; occasional specimens were stained, indicating that this species was the predominant member of the foraminiferal standing crop. *Ammonia beccarii* (Linné) variant and *Hanzawia concentrica* (Cushman) were frequent, but only a single specimen of the former group was alive at the time of sampling. *Elphidium incertum* (Williamson) variant, *Quinqueloculina seminulum* (Linné), and *Quinqueloculina poeyana* d'Orbigny were occasional components of the thanatocoenoesis. A single specimen of *Quinqueloculina poeyana* d'Orbigny was living. Rare components were *Florilus atlanticus* (Cushman) and *Elphidium* sp. *Florilus atlanticus* was alive when the sample was taken.

### *Station 3 (Beaufort Inlet)*

The sediments here consisted of medium to coarse quartz sand and polished fragments of mollusks. A small foraminiferal assemblage was present of which only specimens of *Elphidium gunteri* were living. Empty tests of this species were abundant, however. Occasional empty tests of *Hanzawaia concentrica, Quinqueloculina poeyana,* and *Quinqueloculina seminulum* were found; *Am-*

*monia beccarii* variant and *Globulina* cf. *Globulina gibba* (d'Orbigny) were rare.

*Station 4 (Beaufort Inlet)*

A dredge sample in five meters of water did not contain foraminifera. The material here was mainly fine to medium quartz sand and broken mollusk shells.

*Station 5 (Bird Shoal)*

This locality is a sand flat with scattered patches of *Zostera* and *Crassostrea virginica* reefs. At low tide numerous tubes of *Chaetopterus variopedatus* were visible. Some of the conspicuous animals living on and in the sand were *Mellita quinquiesperforata, Dosinia discus, Aequipecten irradians, Tagelus plebius, Anadara ovalis, Busycon caricum, Nassarius vibex, Uca pugnax, Pagurus longicarpus,* and *Hymeniacidon heliophila.* A sample taken from the bottom of a tidal pool in 0.5 m of water contained the following foraminifera: *Elphidium gunteri,* which was the predominant species alive at the time of sampling; *Quinqueloculina seminulum* (Linné) *jugosa* Cushman, also abundant but consisting of only empty tests; frequent *Hanzawaia concentrica* (all dead). The following were occasional but represented by rare living specimens: *Ammobaculites* cf. *Ammobaculites dilatatus* Cushman and Bronnimann, *Ammonia beccarii*

TABLE 1. LOG OF COLLECTING STATIONS

| Station | Date of Sampling | Remarks |
|---|---|---|
| 1 | 7-9-69 | Atlantic Ocean; in 11 m of water on the continental shelf. Dredge sample from the "Beveridge" |
| 2 | 7-5-69 | Beaufort Inlet; in 8 m of water. Dredge sample |
| 3 | 7-5-69 | Beaufort Inlet; in 4 m of water. Dredge sample |
| 4 | 7-5-69 | Beaufort Inlet; in 5 m of water. Dredge sample |
| 5 | 6-16-69 | Bird Shoal (sand flat), 0.5 m of water. Hand sample by plastic core liner |
| 6 | 7-5-69 | Beaufort Inlet; in 4 m of water. Dredge sample |
| 7 | 6-29-69 | Pivers Island at DUML pier; intertidal zone at low tide. Spade sample. |
| 8A | 6-18-69 | Intertidal pool in marsh across channel from Beaufort fish factory; 0.5 m of water. Hand sample by plastic core liner. |
| 8B | 6-18-69 | Edge of sand flat; in 1.5 m of water. Hand sample by plastic core liner |
| 9 | 6-25-69 | Salt marsh at low tide. Spade sample |
| 10 | 6-25-69 | Bottom of creek in salt marsh at low tide; in 0.5 m of water. Hand sample by plastic core liner |
| 11 | 6-20-69 | Core Creek. Grab sample from the "Beveridge" |
| 12 | 6-20-69 | Core Creek. Grab sample from the "Beveridge" |
| 13 | 6-20-69 | Adams Creek. Grab sample from the "Beveridge" |
| 14 | 6-20-69 | Neuse River. Grab sample from the "Beveridge" |
| 15 | 7-8-69 | Newport River; in 2 m of water. Dredge sample |
| 16 | 7-8-69 | Newport River; in 1.5 m of water. Dredge sample |
| 17 | 7-8-69 | Newport River; in 2 m of water. Dredge sample |
| 18 | 7-8-69 | Newport River; in 1 m of water. Dredge sample |
| 19 | 7-8-69 | Newport River; in 1 m of water. Dredge sample |
| 20 | 7-8-69 | Newport River; in 1 m of water. Dredge sample |
| 21 | 7-9-69 | Newport River at Newport, North Carolina; in 1 m of water. Grab sample |

variant, *Cibicides* cf. *Cibicides refulgens* Montfort, and *Elphidium incertum* variant. Occasional empty tests of *Globigerinoides ruber* (d'Orbigny) and *Globigerinoides conglobatus conglobatus* (Brady) (both small in size) were found. Only the rare, empty tests of the following were found: *Elphidium* sp., *Florilus atlanticus, Globigerinoides quadrilobatus sacculifer* (Brady), *Nodobacullariella* sp., and *Textularia* sp.

*Station 6 (Beaufort Inlet)*

Quartz sand and broken mollusk shells constituted the bulk of this sample, and the detrital origin of the sediment is further attested to by the occurrence of two worn specimens of *Siphogenerina lamellata* Cushman, which could only have been derived from Tertiary beds, since this species is extinct and belongs to a paleoecological position much farther oceanward than the turbulent inlet type of environment. *Elphidium gunteri* was abundant and the dominant living species here. *Ammobaculites* cf. *Ammobaculites dilatatus* and *Quinqueloculina seminulum* were represented by abundant empty tests, but living specimens were only frequent and occasional, respectively. *Ammotium salsum* (Cushman and Bronnimann) was frequent both in empty tests and in living specimens. Frequent empty tests but only occasional living individuals were found for *Ammonia beccarii* variant, *Elphidium incertum* variant, *Hanzawaia concentrica,* and *Psammosphaera fusca* Schulze. Frequent empty tests but no living specimens were recorded for *Buccella hannai* (Phleger and Parker). Occasional dead but only rare living representatives were found for *Cibicides* sp. cf. *Cibicides refulgens, Elphidium* sp., and *Globigerinoides ruber.* Occasional empty tests but no living individuals were seen for *Globigerinoides conglobatus conglobatus* and *Rosalina floridana* (Cushman). *Ammotium* sp. was represented by a single live specimen. Only rare, empty tests were found of *Florilus atlanticus, Globigerinoides quadrilobatus sacculifer, Hastigerina (Hastigerina) siphonifera siphonifera, Quinqueloculina seminulum jugosa,* and *Textularia* sp.

*Station 7 (Pivers Island)*

The upper two centimeters of sand from an area about four centimeters in diameter were removed from the intertidal zone at low tide near the Duke University Marine Laboratory pier, Pivers Island. *Uca pugilator* and *Nassarius obsoletus* were among the more conspicuous animals on the surface of this area. The sediment was mainly fine to medium quartz sand. Large empty tests of tropical and subtropical planktonic foraminiferal species were found among the living specimens, and it is suspected that bottom sediments from the continental slope or deeper oceanic regions may have been dumped at the pier after a voyage by the "Eastward" to a more southern region. Planktonic species noted were *Pulleniatina obliquiloculata obliquiloculata* (Parker and Jones), *Globorotalia (Globorotalia) menardii* (Parker, Jones and Brady), *Globigerinoides quadrilobatus sacculifer* (Brady), *Globigerinoides ruber* (d'Orbigny), *Globigerinoides conglobatus conglobatus* (Brady), *Globorotalia (Globorotalia) truncatulinoides* (d'Orbigny), and *Globoquadrina dutertrei* (d'Orbigny). The living population was dominated by *Elphidium gentri* and *Ammonia beccarii* variant (both abundant). *Ammotium salsum, Ammonia beccarii* variant and *Elphidium* sp. A were frequent but only occasional in living specimens. Only the empty tests of *Trochammina laevigata* were observed (frequent). Occasional empty tests were found of *Ammobaculites* cf. *Ammobaculites dilatatus, Buccella hannai,* and *Hanzawaia concentrica.* Of these, only the first was living at the time of sampling. Rare, dead specimens of *Florilus atlanticus* and *Quinqueloculina seminulum* were seen.

*Station 8A (Intertidal Pool)*

An intertidal pool in a *Spartina* marsh with a bottom of silt, very fine quartz sand, and plant fibers yielded occasional living specimens of *Ammobaculites* cf. *Ammobaculites dilatatus* and *Ammotium salsum.* The former was frequent in a subsequent sampling. This is a rather low standing crop, and it is possible that these species may have been living in a higher frequency in the surrounding marsh among the densely matted roots of *Spartina.*

*Station 8B (Sand Flat)*

A sample from the edge (at low tide) of the above marsh in 1.5 m of water with a

higher percentage of fine to medium quartz sand was more productive, as shown below:

| Species | Empty Tests | Live Specimens |
|---|---|---|
| *Ammobaculites* cf. *Ammobaculites dilatatus* Cushman and Bronnimann | occasional | occasional |
| *Ammonia beccarii* (Linné) variant | 0 | rare |
| *Ammotium salsum* (Cushman and Bronnimann) | frequent | occasional |
| *Elphidium gunteri* Cole | abundant | frequent |
| *Hanzawaia concentrica* (Cushman) | occasional | 0 |
| *Psammosphaera fusca* Schulze | occasional | 0 |

### *Station 9 (Salt Marsh)*

This locality, a *Spartina* marsh with abundant burrows of the fiddler crab, *Uca minax,* was sampled at low tide about 25 meters from standing water. Although the marsh surface at low tide easily bears the weight of a man, the ground never dries appreciably, the mud and matted roots of dense *Spartina alterniflora* retaining enough saline water to be soggy. The residue was dominantly fine to medium quartz sand with abundant plant fragments and foraminifera. Salinity at the surface becomes drastically reduced with heavy periodic rains. The diatom, *Coscinodiscus* sp. was abundant. The foraminiferal population is shown as follows:

| Species | Empty Tests | Live Specimens |
|---|---|---|
| *Ammonia beccarii* (Linné) variant | 0 | abundant |
| *Ammotium pseudocassis* Cushman and Bronnimann | abundant | abundant |
| *Arenoparrella mexicana* (Kornfeld) | abundant | abundant |
| *Haplophragmoides wilberti* Anderson | abundant | abundant |
| *Miliammina beaufortensis,* n. sp. | abundant | abundant |
| *Miliammina fusca* (H. B. Brady) | abundant | abundant |
| *Psammosphaera* sp. | abundant | abundant |
| *Siphotrochammina lobata* Saunders | abundant | abundant |
| *Sulcophax palustris* Warren | frequent | 0 |
| *Textularia palustris* Warren | abundant | frequent |
| *Tiphotrocha comprimata* (Cushman and Bronnimann) | abundant | abundant |
| *Trochamminita irregularis* Cushman and Bronnimann | abundant | abundant |
| *Trochammina laevigata* Cushman and Bronnimann | abundant | abundant |

Although rare in relation to total fauna, over 100 specimens of *Ammonia beccarii* variant were found (pl. 3, figs. 3–4). All of these were alive, and most were corroded, suggesting that acid conditions in marshes may dissolve the empty tests of calcareous forms, as postulated by Lankford (1959, p. 2077) and Parker and Athearn (1959, p. 338).

### *Station 10 (Stream in Salt Marsh)*

A relatively poor fauna was recovered from the bottom of a flowing creek in another salt marsh. The water in this stream was 0.5 meters deep at low tide.

| Species | Empty Tests | Live Specimens |
|---|---|---|
| *Ammobaculites* cf. *Ammobaculites dilatatus* | occasional | 0 |
| *Arenoparrella mexicana* | occasional | 0 |
| *Miliammina fusca* | occasional | 0 |
| *Tiphotrocha comprimata* | frequent | occasional |
| *Trochammina laevigata* | frequent | rare |

Stations 11 to 14 are in creek and river channels. Samples were recovered by dredge from the "Beveridge". Phleger (1960, pp. 159–160) has referred to this type of milieu as the "fluvial marine" environment, that is, essentially an estuary where there is an invasion of a salt-water wedge along the bottom. Salinity is highly variable depending upon the tides and rainfall. A range in salinity was found in this series of stations from 35.7‰ to 12.4‰ for the bottom waters. Salinity of surface waters ranged from 34.1‰ to 10.6‰.

### *Station 11 (Core Creek)*

Water depth, 5 m. Salinity of upper water, 34.1‰; bottom, 35.7‰. Temperature of upper water, 83°F; bottom, 83°F.

| Species | Empty Tests | Live Specimens |
|---|---|---|
| *Ammobaculites crassus* Warren | rare | 0 |
| *Ammonia beccarii* variant | rare | 0 |
| *Ammotium salsum* | abundant | frequent |
| *Elphidium incertum* variant | abundant | occasional |
| *Elphidium* sp. A | frequent | 0 |
| *Hanzawaia concentrica* | rare | 0 |
| *Haplophragmoides wilberti* | rare | 0 |

### *Station 12 (Core Creek)*

Water depth, 4–5 m. Salinity of upper water, 26.8‰; bottom, 27.3‰. Temperature of upper water, 82°F; bottom, 82°F.

| Species | Empty Tests | Live Specimens |
|---|---|---|
| *Ammonia beccarii* variant | abundant | 0 |
| *Elphidium gunteri* | rare | 0 |
| *Quinqueloculina seminulum jugosa* | rare | 0 |

This was a sparse foraminiferal assemblage. The stream current apparently was fast at the exact location from which the sample was obtained. The sediment here was mainly medium to coarse quartz sand and broken mollusk shells.

### *Station 13 (Adams Creek)*

Water depth, 5 m. Salinity of upper water, 18.3‰; bottom, 27.8‰. Temperature of upper water, 83°F; bottom, 82.5°F.

| Species | Empty Tests | Live Specimens |
|---|---|---|
| *Ammobaculites crassus* | frequent | rare |
| *Ammonia beccarii* variant | rare | 0 |
| *Ammotium salsum* | occasional | rare |
| *Trochammina laevigata* | rare | 0 |

### *Station 14 (Neuse River)*

Water depth, 3–4 m. Salinity of upper water, 10.6‰; bottom, 12.4‰. Temperature of upper water, 81.5°F; bottom, 83°F.

| Species | Empty Tests | Live Specimens |
|---|---|---|
| *Ammoastuta inepta* (Cushman and McCulloch) | rare | 0 |
| *Ammobaculites crassus* | abundant and predominant | |
| *Ammobaculites subcatenulatus* Warren | abundant | abundant |
| *Ammodiscus* (?) sp. | 0 | rare |
| *Ammonia beccarii* variant | frequent | frequent |
| *Ammotium salsum* | abundant and predominant | |
| *Elphidium incertum* variant | 0 | rare |
| *Haplophragmoides wilberti* | occasional | 0 |
| *Miliammina fusca* | abundant | abundant |

A complete salinity range in fluvial marine environments was provided by seven stations in the Newport river. The sediment in all seven samples was predominantly plant fibers and fine silt. Oyster beds were in proximity to stations 16–18. The salinity varies here with the tides and rainfall. Over a year, the bottom salinity has varied between 11.3 and 28‰ at station 16 according to Mr. John Culliney of Duke University Marine Laboratory. At station 20 bottom salinity is known to vary between 1.3 and 27.4‰. The salinity of the Newport river at Newport, North Carolina (station 21), is usually close to 0‰, but during periods of drouth, it may rise to 1 or 2‰ in the bottom of the channel. Surface salinities at the time of sampling (high tide, July 8, 1969) were as follows: station 15, 33.8‰; station 16, 33.7‰; station 17, 20.0‰; station 18, 19.5‰; and station 19, 5.6‰. The species found at these stations are shown in the following tables:

### *Station 15*

| Species | Empty Tests | Live Specimens |
|---|---|---|
| *Ammonia beccarii* variant | occasional | 0 |
| *Elphidium gunteri* | frequent | occasional |
| *Elphidium incertum* variant | 0 | rare |

### *Station 16*

| | | |
|---|---|---|
| *Ammonia beccarii* variant | abundant | rare |
| *Elphidium gunteri* | frequent | 0 |
| *Elphidium incertum* variant | abundant | occasional |

### *Station 17*

| | | |
|---|---|---|
| *Ammobaculites crassus* | occasional | occasional |
| *Ammonia beccarii* variant | abundant | frequent |
| *Ammotium salsum* | abundant | abundant |
| *Elphidium gunteri* | abundant | abundant |
| *Elphidium incertum* variant | rare | occasional |
| *Elphidium* sp. | abundant | abundant |
| *Miliammina fusca* | 0 | rare |

Diatoms were abundant at station 17.

### *Station 18*

| | | |
|---|---|---|
| *Ammoastuta inepta* | frequent | 0 |
| *Ammobaculites crassus* | rare | 0 |
| *Ammonia beccarii* variant | abundant | occasional |
| *Ammotium salsum* | abundant | 0 |
| *Elphidium gunteri* | abundant | 0 |
| *Elphidium incertum* variant | abundant | 0 |
| *Haplophragmoides manilaensis* Andersen | rare | 0 |
| *Haplophragmoides wilberti* | frequent | 0 |
| *Tiphotrocha comprimata* | occasional | 0 |

Thecamoebians were present but quite rare.

### *Station 19*

| | | |
|---|---|---|
| *Ammobaculites crassus* | abundant | 0 |
| *Ammotium salsum* | abundant | abundant |
| *Arenoparrella mexicana* | frequent | 0 |
| *Haplophragmoides manilaensis* | occasional | 0 |
| *Haplophragmoides wilberti* | frequent | 0 |
| *Miliammina fusca* | frequent | 0 |
| *Tiphotrocha comprimata* | rare | 0 |
| *Trochammina laevigata* | occasional | 0 |

All of the species in the above list are arenaceous. The bottom sediments here consisted mainly of fine to medium quartz sand.

### *Station 20*

| | | |
|---|---|---|
| *Ammoastuta inepta* | abundant | 0 |
| *Ammobaculites crassus* | abundant | rare |
| *Ammotium salsum* | abundant | frequent |
| *Arenoparrella mexicana* | abundant | 0 |
| *Haplophragmoides manilaensis* | frequent | 0 |
| *Haplophragmoides wilberti* | abundant | 0 |
| *Miliammina fusca* | abundant | rare |
| ?*Psammosphaera* sp. | abundant | 0 |
| *Tiphotrocha comprimata* | abundant | 0 |
| *Trochammina laevigata* | abundant | 0 |

Diatoms, particularly *Coscinodiscus*, were abundant.

### *Station 21*

| | | |
|---|---|---|
| *Ammoastuta inepta* | rare | 0 |
| *Ammobaculites crassus* ? | rare | 0 |
| *Trochammina laevigata* ? | rare | 0 |

All of the above specimens were extremely small. *Coscinodiscus* was abundant, and at least five species and perhaps as many genera of thecamoebians were present.

## IV. Distribution (Below Sediment Surface) of Living Foraminifera in a Salt Marsh

A sample was collected 30 cm below the sediment surface at station 9 by spade and with direct measurement of the depth. Care was taken to avoid the numerous *Uca* burrows in the area. The penetrated material was soggy, as was the surface of this intertidal marsh, and water flowed into the bottom of the excavation within a few minutes. The sample, even at 30 cm below the surface, was mostly a mat of *Spartina alterniflora* with clay and fine silt size sediment. The

following foraminifera were counted in 50 cubic centimeters of wet material from a depth of 30 cm below the marsh surface:

| Species | Empty Tests | Live Specimens |
|---|---|---|
| *Arenoparrella mexicana* | 81 | 17 |
| *Miliammina fusca* | 11 | 0 |
| *Siphotrochammina lobata* | 4 | 0 |
| *Tiphotrocha comprimata* | 49 | 5 |
| *Trochammina laevigata* | 45 | 5 |

The above data for living specimens prompted a subsequent investigation approximately two weeks later in the same area, again at low tide. A second hole was dug about 25 meters from the first, again 25 meters from standing water. The results from this excavation (each sample consisting of 50 cubic centimeters of wet material) were as follows:

5–10 cm below the sediment surface

| | | |
|---|---|---|
| *Arenoparrella mexicana* | 3 | 0 |
| *Miliammina fusca* | 14 | 1 |
| *Tiphotrocha comprimata* | 2 | 0 |
| *Trochammina laevigata* | 28 | 1 |

10–20 cm below the sediment surface

| | | |
|---|---|---|
| *Ammonia beccarii* variant | 1 | 0 |
| *Arenoparrella mexicana* | 10 | 0 |
| *Miliammina fusca* | 43 | 0 |
| *Tiphotrocha comprimata* | 7 | 0 |
| *Trochammina laevigata* | 31 | 2 |

15–20 cm below the sediment surface

| | | |
|---|---|---|
| *Ammonia beccarii* variant | 0 | 1 |
| *Arenoparrella mexicana* | 39 | 2 |
| *Miliammina fusca* | 26 | 1 |
| *Tiphotrocha comprimata* | 19 | 5 |
| *Trochammina laevigata* | 52 | 5 |

25–30 cm below the sediment surface

| | | |
|---|---|---|
| *Arenoparrella mexicana* | 18 | 2 |
| *Miliammina fusca* | 14 | 1 |
| *Tiphotrocha comprimata* | 28 | 0 |
| *Trochammina laevigata* | 66 | 5 |

30–35 cm below the sediment surface

| | | |
|---|---|---|
| *Arenoparrella mexicana* | 19 | 0 |
| *Miliammina fusca* | 39 | 4 |
| *Siphotrochammina lobata* | 15 | 0 |
| *Tiphotrocha comprimata* | 32 | 2 |
| *Trochammina laevigata* | 90 | 7 |

35–40 cm below the sediment surface

| | | |
|---|---|---|
| *Ammobaculites* sp. | 4 | 0 |
| *Ammonia beccarii* variant | 6 | 0 |
| *Arenoparrella mexicana* | 15 | 0 |
| *Miliammina fusca* | 38 | 0 |
| *Siphotrochammina lobata* | 13 | 0 |
| *Tiphotrocha comprimata* | 14 | 0 |
| *Trochammina laevigata* | 58 | 1 |

45–50 cm below the sediment surface

| | | |
|---|---|---|
| *Ammobaculites* sp. | 2 | 0 |
| *Ammonia beccarii* variant | 8 | 0 |
| *Arenoparrella mexicana* | 18 | 0 |
| *Miliammina fusca* | 13 | 0 |
| *Siphotrochammina lobata* | 18 | 0 |
| *Tiphotrocha comprimata* | 41 | 0 |
| *Trochammina laevigata* | 39 | 0 |

## V. Discussion

The term, "estuarine," as used in the title of this report, includes a variety of environments that have been referred to as "marginal marine" (Phleger, 1960, p. 125), and a tabulation of such areas includes marine marshes, rivers, lagoons and bays, beaches, and the adjacent portion of the continental shelf. A glimpse of all of these in the Beaufort area reveals similarities with other regions, such as Barnstable, Massachusetts (Phleger and Walton, 1950), Poponesset Bay, Massachusetts (Parker and Athearn, 1959), Long Island Sound (Parker, 1952), San Antonio Bay, Texas (Parker *et al.,* 1953), and the Mississippi delta area (Phleger, 1955; Lankford, 1959), particularly in the generic composition of foraminiferal faunas of the various types of marginal marine environments. The assemblage at station 1, for example, has a relatively high generic and species diversity similar to assemblages elsewhere from the open-ocean nearshore environment. Lagoonal faunas, such as those at stations 6, 7, and 8, have a lower species diversity index and are characterized by a few species of the calcareous genera, *Elphidium* and *Ammonia,* and a few species of the arenaceous genera, *Trochammina* and *Ammobaculites.* A similarity between fluvial marine and salt marsh faunas has been noted by Phleger (1960, p. 153), and this relationship holds for the study area, although the extremely high frequency of several arenaceous species living at station 14 appears to be quite distinctive for the upper reaches of an estuary (Neuse River). *Ammobaculites crassus*, in particular, constituted a high standing crop at this station and may, with investigation of other estuaries of the Atlantic coast, prove to be an "ecological marker" in fluvial marine environments with the salinity range at station 14.

A low species diversity is also characteristic of marsh faunas, and some of the species have a very wide geographic distribution. Phleger (1960, p. 175) has noted that *Ammoastuta inepta* has world-wide distribution, being reported from Trinidad, California, northern Gulf of Mexico, northeastern United States, Panama, and Ecuador. It was abundant at station 20 in the narrow Newport River bed. None of the specimens were alive at the time of sampling, and all of the empty tests were probably derived by outwashing from the surrounding marsh. Other characteristic species of Gulf of Mexico–

Caribbean marshes which also occur in the station 9 marsh in very high frequency are *Trochammina laevigata, Miliammina fusca, Arenoparrella mexicana,* and *Tiphotrocha comprimata.* To our knowledge, this is the first report of living foraminifera (at station 9) at some distance from a body of water. The abundance of stained specimens strongly suggests that the intertidal *Spartina* marsh is the preferred habitat for these species.

Stations in the upper reaches of the Newport River are additional documentation that foraminifera thrive in saline waters but give way to the Thecamoebina when there is no longer a tidal (saline) influence. Foraminifera may be abundant in even brackish environments of periodical low salinity, but they diminish as the salinity approaches 1‰. The thecamoebians, on the other hand, thrive in fresh water streams (Bolli and Saunders, 1954) and diminish toward saline water.

Several arenaceous species of foraminifera were found living at a depth of 30–35 cm and a single specimen of *Trochammina laevigata* at 35–40 cm below the sediment surface in an intertidal *Spartina* marsh at low tide. These are the deepest recorded occurrences of foraminifera living below the sediment surface.

Phleger (1960, p. 177) has suggested that calcareous tests cannot survive the low pH of marsh environments. This may be the reason that mostly foraminifera with arenaceous tests have been found so deep below the sediment surface. No pH values were available for the present report, and this is indeed a factor for which more data are needed.

## VI. Systematics

Order Foraminifera Eichwald, 1830
Suborder Textulariina Delage and Herouard, 1896
Superfamily Ammodiscacea Reuss, 1862
Family Saccamminidae Brady, 1884
Subfamily Psammosphaerinae Haeckel, 1894
Genus Psammosphaera Schulze, 1875

### Psammosphaera fusca Schulze

*Psammosphaera fusca* Schulze, 1875, Comm. Wiss. Untersuchung Deutsch. Meere Kiel, Jahresber., Jahrg. 2–3, p. 113, pl. 2, figs. 8a–f.

Two specimens were found at station 8B.

### ?Psammosphaera sp.

Plate 1, fig. 5

This is a variable form in which the aperture is in the end of a short, simple neck. Some specimens have a single aperture; others have two and even three.

The species, although abundant at station 9, was not found elsewhere in the Beaufort area.

Family Ammodiscidae Reuss, 1862
Subfamily Ammodiscinae Reuss, 1862
Genus Ammodiscus Reuss, 1862

### Ammodiscus (?) sp.

A single specimen was found at station 14.

Superfamily Lituolacea de Blainville, 1825
Family Hormosinidae Haeckel, 1894
Subfamily Hormosininae Haeckel, 1894
Genus Sulcophax Rhumbler in Wiesner, 1931

### Sulcophax palustris Warren

Plate 1, fig. 6

*Sulcophax palustris* Warren, 1957, Cushman Found. Foram. Res., Contr., v. 8, pt. 1, p. 31, pl. 3, figs. 1–4.

Rare specimens from station 9 are identical with Warren's specimens from the Buras-Scofield Bayou region of southeast Louisiana. Comparisons were made with the holotype (LSU Geology Museum Locality No. 2009). The occurrence here is the first record of this species outside of the type locality (Buras-Scofield Bayou, Louisiana).

Family Rzehakinidae Cushman, 1933
Genus Miliammina Heron-Allen and Earland, 1930

### Miliammina beaufortensis, new species

Plate 4, figs. 1–3

Test small, elongate oval, half as thick as broad; length almost twice the width. Chambers in quinqueloculine arrangement. Wall agglutinated, composed of minute, tabular particles, oriented so as to present a smooth, polished surface, pale tan to buff in color. Aperture an elongate arch above penultimate chamber, without tooth but with external low ridge, almost as wide as opening, arising threshold-like from penultimate chamber.

Length of holotype (Pl. 4, figs. 2a–c), 0.27 mm, breadth, 0.15 mm, thickness, 0.12 mm.

*Miliammina beaufortensis* is similar to *Miliammina pariaensis* Todd and Bronnimann in the texture and smooth, polished appearance of the test wall and in the incipient spiroloculine arrangement of the later chambers. The Beaufort form, however, is not so compressed as the larger Trinidad species and characteristically has a low threshold-like ridge below and external to the aperture which is not seen in *Miliammina pariaensis*.

MILIAMMINA FUSCA (H. B. Brady)
Plate 1, fig. 1

*Quinqueloculina fusca* H. B. BRADY, 1870, Ann. Mag. Nat. Hist., ser. 4, v. 6, p. 47, pl. 11, figs. 2a–c, 3.
*Miliammina fusca* (H. B. Brady). TODD AND BRONNIMANN, 1957, Cushman Found. Foram. Res., Spec. Publ., no. 3, p. 26, pl. 3, fig. 1.

Specimens from the Beaufort area are conspecific with those from estuarine environments of the Gulf of Mexico–Caribbean region that have been assigned by various authors to this taxon.

Family LITUOLIDAE de Blainville, 1825
Subfamily HAPLOPHRAGMOIDINAE Maync, 1952
Genus HAPLOPHRAGMOIDES Cushman, 1910

HAPLOPHRAGMOIDES MANILAENSIS Andersen

*Haplophragmoides manilaensis* ANDERSEN, 1953, Cushman Found. Foram. Res., Contr., v. 4, pt. 1, p. 22, pl. 4, figs. 8a, b.

Specimens are typical.

HAPLOPHRAGMOIDES WILBERTI Andersen
Plate 1, fig. 4

*Haplophragmoides wilberti* ANDERSEN, 1953, Cushman Found. Foram. Res., Contr., v. 4, pt. 1, p. 21, pl. 4, figs. 7a, b.

Specimens are typical and abundant in the salt marsh environment.

Genus TROCHAMMINITA Cushman and Bronnimann, 1948

TROCHAMMINITA IRREGULARIS Cushman and Bronnimann
Plate 1, fig. 2

*Trochamminita irregularis* CUSHMAN AND BRONNIMANN, 1948, Cushman Lab. Foram. Research, Contr., v. 24, pt. 1, p. 17, pl. 4, figs. 1–3.

This species is abundant at station 9, but specimens with typical apertures are rare. The test is extremely fragile, and several specimens bearing apertures were broken when they were manipulated for photography. The geographic range of *Trochamminita irregularis,* which was originally described from brackish waters of Trinidad and later reported from polyhaline marshes of coastal Louisiana, is extended to the Beaufort area by this investigation.

Subfamily LITUOLINAE de Blainville, 1825
Genus AMMOASTUTA Cushman and Bronnimann, 1948

AMMOASTUTA INEPTA (Cushman and McCulloch)
Plate 1, fig. 3

*Ammobaculites ineptus* CUSHMAN AND MCCULLOCH, 1939, Allan Hancock Pacific Exped., v. 6, no. 1, p. 89, pl. 7, fig. 6.
*Ammoastuta salsa* CUSHMAN AND BRONNIMANN, 1948, Cushman Lab. Foram. Research, Contr., v. 17, pt. 3, p. 17, pl. 3, figs. 14–16.
*Ammoastuta inepta* (Cushman and McCulloch). TODD AND BRONNIMANN, 1957, Cushman Found. Foram. Res., Spec. Publ., no. 3, p. 23 (not figured).

This species is found in the Beaufort area at several stations where the water is fresh enough to drink. It was not found at stations with salinity higher than 19.5‰.

Genus AMMOBACULITES Cushman, 1910

AMMOBACULITES CRASSUS Warren
Plate 2, figs. 3–4

*Ammobaculites crassus* WARREN, 1957, Cushman Found. Foram. Res., Contr., v. 8, pt. 1, p. 32, pl. 3, figs. 5–7.

Sediment from station 14 (Neuse River) literally teems with large specimens of this species. Many individuals have chambers in excess of the maximum reported by Warren for the taxon.

AMMOBACULITES cf. AMMOBACULITES DILATATUS Cushman and Bronnimann

*Ammobaculites dilatatus* CUSHMAN AND BRONNIMANN, 1948, Cushman Lab. Foram. Res., Contr., v. 24, pt. 2, p. 39, pl. 7, figs. 10, 11.

Rare specimens were found at a few of the estuarine stations.

### Ammobaculites subcatenulatus Warren

*Ammobaculites subcatenulatus* Warren, 1957, Cushman Found. Foram. Res., Contr., v. 8, pt. 1, p. 32, pl. 3, figs. 11–13.

This species was abundant only at station 14 in the Neuse River.

## Genus Ammotium Loeblich and Tappan, 1953

### Ammotium pseudocassis (Cushman and Bronnimann)

Plate 2, fig. 1

*Ammobaculites pseudocassis* Cushman and Bronnimann, 1948, Cushman Lab. Foram. Res., Contr., v. 24, pt. 2, p. 39, pl. 7, figs. 12a, b.

This variable form is abundant at station 9.

### Ammotium salsum (Cushman and Bronnimann)

Plate 2, fig. 2

*Ammobaculites salsus* Cushman and Bronnimann, 1948, Cushman Lab. Foram. Res., Contr., v. 24, pt. 1, p. 16, pl. 3, figs. 7–9.

This species is characteristic of the fluvial estuarine stations 14–20.

## Family Textulariidae Ehrenberg, 1838
## Subfamily Textulariinae Ehrenberg, 1838
## Genus Textularia Defrance *in* de Blainville, 1824

### Textularia palustris Warren

Plate 2, fig. 7

*Textularia palustris* Warren, 1957, Cushman Found. Foram. Res., Contr., v. 8, pt. 1, p. 34, pl. 4, figs. 3–5.

Specimens were compared with the holotype from Louisiana, and they are identical. The species was observed only at station 9 in the Beaufort area.

### Textularia sp.

A single fragment, unidentifiable as to species, was found at station 6.

## Family Trochamminidae Schwager, 1877
## Subfamily Trochammininae Schwager, 1877
## Genus Trochammina Parker and Jones, 1859

### Trochammina laevigata Cushman and Bronnimann

Plate 2, fig. 5

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→

### Plate 1

Figure

1 *Miliammina fusca* (H. B. Brady)
- a, b Opposite sides, × 146
  Length, 0.42 mm; breadth, 0.20 mm

2 *Trochamminita irregularis* Cushman and Bronnimann
- a, b Opposite sides, × 160
  Length, 0.39 mm; breadth, 0.16 mm

3 *Ammoastuta inepta* (Cushman and McCulloch)
- a Side view, × 154
- b Apertural view, × 656
  Length, 0.42 mm; breadth, 0.25 mm

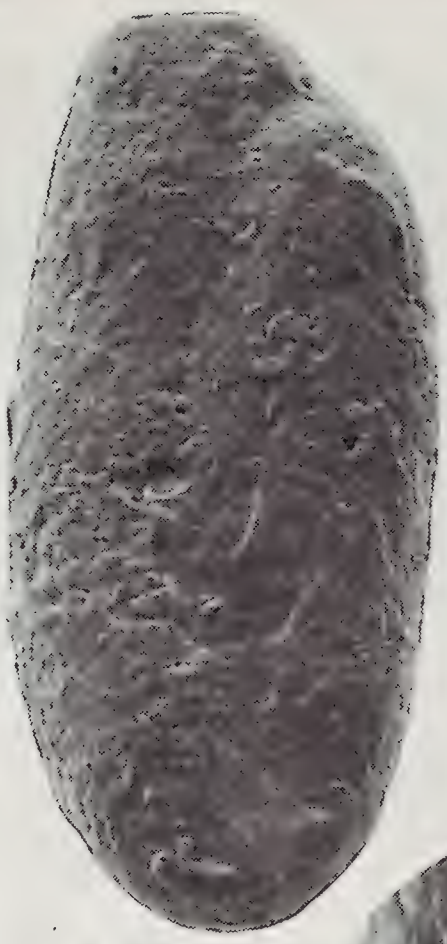
4 *Haplophragmoides wilberti* Andersen
- a Edge view, × 160
- b Side view, × 160
  Maximum diameter, 0.39 mm; thickness, 0.19 mm

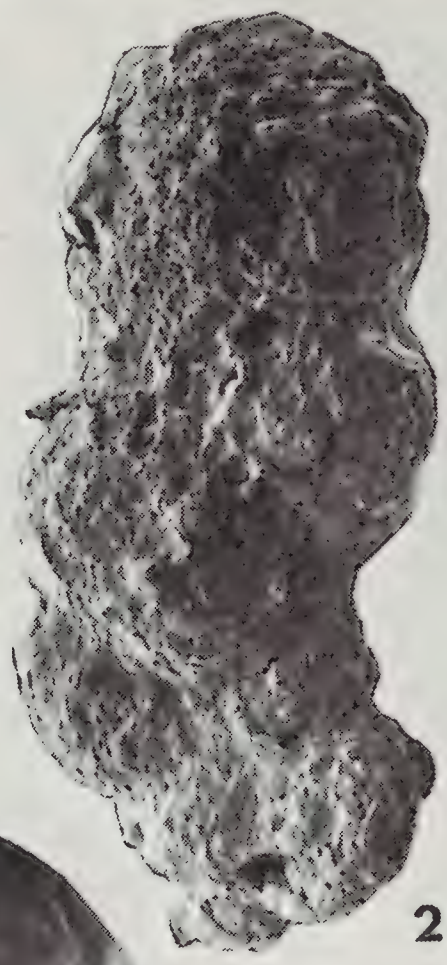
5 ? *Psammosphaera* sp.
× 160
Maximum diameter, 0.36 mm

6 *Sulcophax palustris* Warren
× 107
Length (early portion lost), 0.46 mm

Figure 3, Station 20; all others, Station 9.

1a


1 b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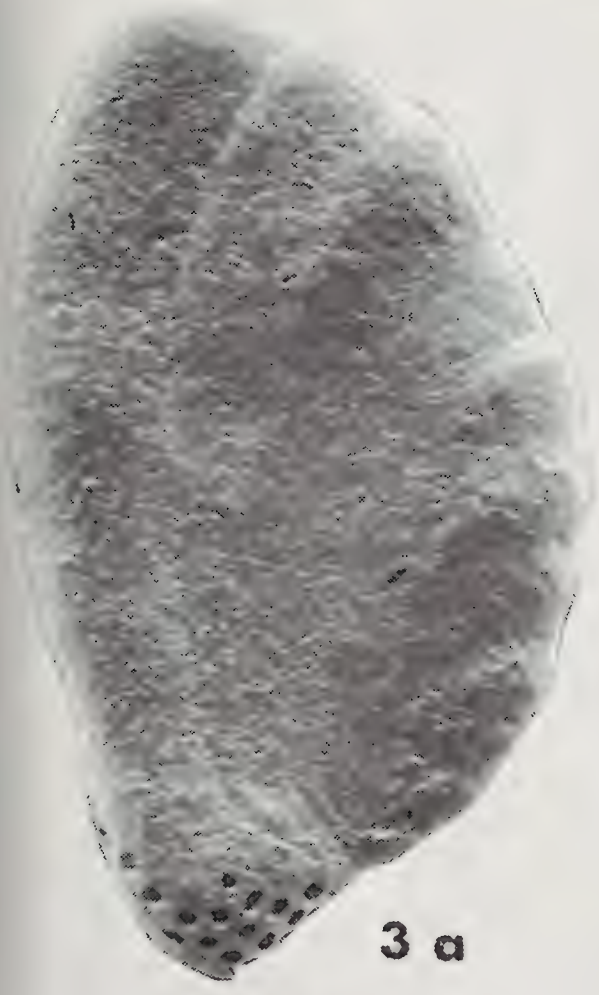
2 b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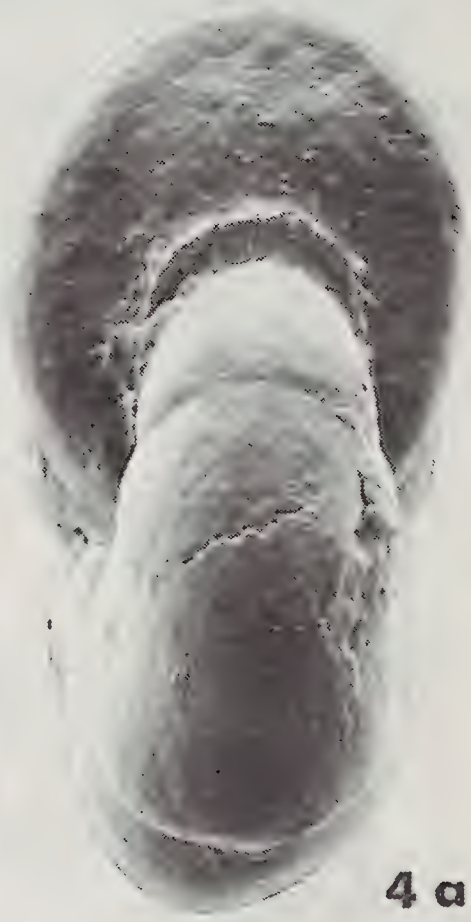
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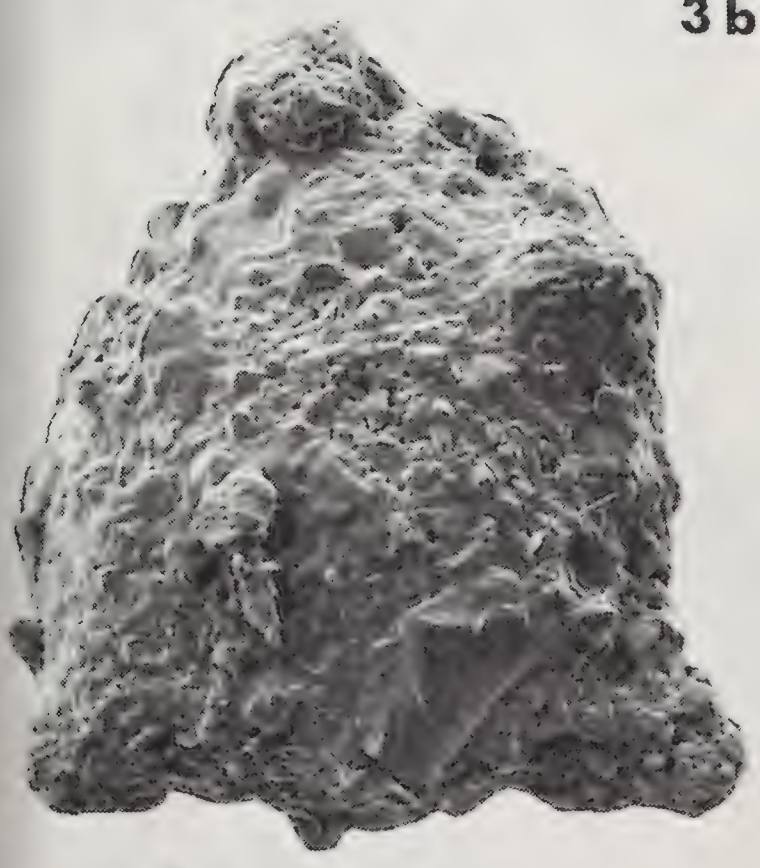
4 b


5

6

PLATE 1

*Trochammina laevigata* Cushman and Bronnimann, 1948, Cushman Lab. Foram. Res., Contr., v. 24, pt. 2, p. 41, pl. 7, figs. 21, 22.

This species was abundant at station 9 both at the marsh surface and below the sediment surface. Specimens are identical with forms from Trinidad and the northern Gulf of Mexico.

### Trochammina sp.

A few specimens, unidentifiable as to species, were found at station 1.

## Genus Arenoparrella Andersen, 1951

### Arenoparrella mexicana (Kornfeld)
Plate 2, fig. 6

*Trochammina inflata* (Montagu) var. *mexicana* Kornfeld, 1931, Contr. Stanford Univ. Geol. Dept., v. 1, p. 86, pl. 13, figs. 5a–c.
*Arenoparrella mexicana* (Kornfeld). Andersen, 1951, Jour. Paleontology, v. 25, no. 1, p. 31, figs. 1a–c.

Beaufort specimens are typical. The highest frequencies observed were at stations 9 and 20.

## Genus Siphotrochammina Saunders, 1957

### Siphotrochammina lobata Saunders
Plate 3, fig. 1

*Siphotrochammina lobata* Saunders, 1957, Smithsonian Misc. Collections, v. 134, no. 5, pp. 9–10, pl. 3, figs. 1, 2.

This species was abundant in the marsh at station 9. It was not identified at any of the other localities.

## Genus Tiphotrocha Saunders, 1957

### Tiphotrocha comprimata (Cushman and Bronnimann)
Plate 3, fig. 2

*Trochammina comprimata* Cushman and Bronnimann, 1948, Cushman Lab. Foram. Res., Contr., v. 24, pt. 2, p. 41, pl. 8, figs. 1–3.
*Tiphotrocha comprimata* (Cushman and Bronnimann). Saunders, 1957, Smithsonian Misc. Collections, v. 134, no. 5, pp. 11–12, pl. 4, figs. 1–4.

Specimens from the Beaufort area are identical with forms from Trinidad and the northern Gulf of Mexico. Living specimens are characteristic of the marsh environment.

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## Plate 2

Figure
1 *Ammotium pseudocassis* (Cushman and Bronnimann)
Side view, × 90
Length, 0.73 mm; maximum width, 0.19 mm
2 *Ammotium salsum* (Cushman and Bronnimann)
a Side view, × 55
b Edge view, × 55
Length, 1.04 mm; thickness, 0.22 mm
3 *Ammobaculites crassus* Warren
a Side view, × 45
b Edge view, × 45
Length, 1.47 mm
4 *Ammobaculites crassus* Warren
Side view, × 44
Length, 1.19 mm
5 *Trochammina laevigata* Cushman and Bronnimann
a, b Opposite sides, × 84
Maximum diameter, 0.68 mm
6 *Arenoparrella mexicana* (Kornfeld)
a, b Opposite sides, × 98
Maximum diameter, 0.50 mm
7 *Textularia palustris* Warren
× 161
Length, 0.43 mm

Figures 2, 3, 4, Station 14; all others, Station 9.

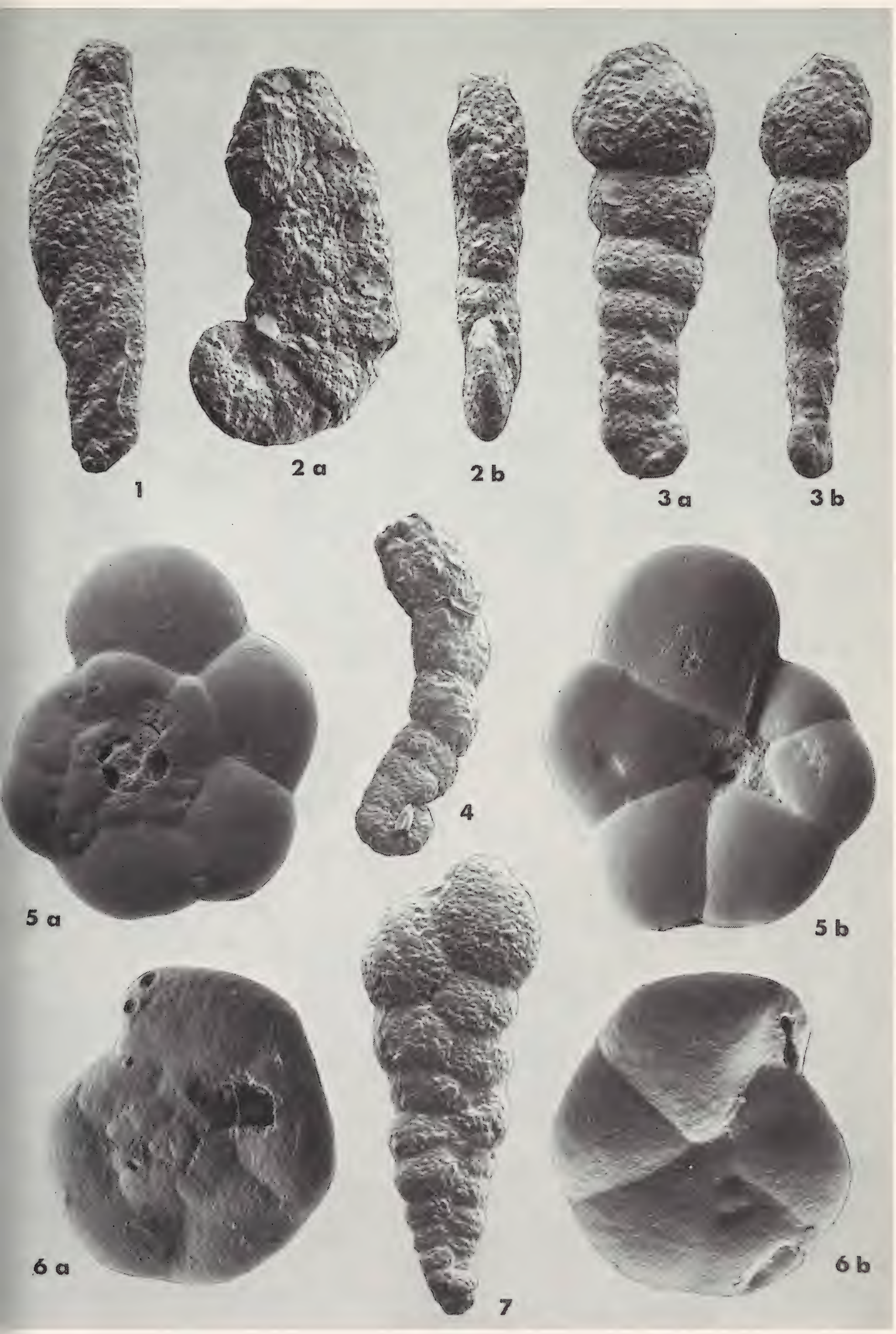


PLATE 2

## VII. Faunal References (Neritic and Outer Estuarine Foraminifera)

Calcareous foraminifera, with the notable exception of *Ammonia beccarii* variant, were found only at the neritic and outer estuarine stations (station 1 to station 8B). Following is an alphabetized reference list of all of the calcareous forms identified in this study:

### Planktonic Forms

*Globigerina bulloides bulloides* d'Orbigny = *"Polymorphium tuberosum et globiferum"* Soldani, 1791 (part), Testaceogr. ac Zoophytogr., vol. 1, pt. 2, p. 117, pl. 123, fig. 0.

*Globigerinoides conglobatus conglobatus* (Brady) =*Globigerina conglobata* Brady, 1879, Quart. Jour. Micros. Sci., new ser., v. 19, p. 286.

*Globigerinoides quadrilobatus sacculifer* (Brady) = *Globigerina sacculifer* Brady, 1877, Geol. Mag., new ser., decade 2, v. 4, no. 12, p. 535.

*Globigerinoides ruber* (d'Orbigny) = *Globigerina rubra* d'Orbigny, 1839, *in* de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères", p. 82, pl. 4, figs. 12–14.

*Hastigerina* (*Hastigerina*) *siphonifera siphonifera* (d'Orbigny) = *Globigerina siphonifera* d'Orbigny, 1839, *in* de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères", p. 83, pl. 4, figs. 15–18.

*Orbulina universa* d'Orbigny, 1839, *in* de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères", p. 2, pl. 1, fig. 1 (*fide* Ellis and Messina, 1940 *et seq.*)

### Benthonic Forms

*Ammonia beccarii* (Linné) variant $\overset{?}{=}$ *Nautilus beccarii* Linné, 1758, Syst. Nat., ed. 10, p. 710.

This is one of the few calcareous forms composing the inner estuarine foraminiferal assemblages in the Beaufort area. See discussion under station 9.

*Buccella hannai* (Phleger and Parker) = *Eponides hannai* Phleger and Parker, 1951, Geol. Soc. America, Mem. 46, pt. 2, p. 21, pl. 10, figs. 11–14.

*Cibicides pseudoungerianus* (Cushman) = *Truncatulina pseudoungeriana* Cushman, 1922, U. S. Geol. Surv. Prof. Paper, no. 129-E, p. 97, pl. 20, fig. 9.

*Cibicides* cf. *Cibicides refulgens* Montfort $\overset{?}{=}$ *Cibicides refulgens* Montfort, 1808, Conch. Syst., v. 1, p. 122.

*Elphidium gunteri* Cole, 1931, Florida State Geol. Surv., Bull. 6, p. 34, pl. 4, figs. 9, 10.

*Elphidium incertum* (Williamson) variant $\overset{?}{=}$ *Polystomella umbilicatula* Walker and Boys var. *incerta* Williamson, 1858, Rec. Foram. Great Britain, p. 44, pl. 3, fig. 82a.

*Florilus atlanticus* (Cushman) = *Nonionella atlantica* Cushman, 1947, Cushman Lab. Foram. Res., Contr., v. 23, pt. 4, p. 90, pl. 20, figs. 4, 5.

*Globulina* cf. *Globulina gibba* (d'Orbigny) $\overset{?}{=}$ *Polymorphina* (*Globuline*) *gibba* d'Orbigny, 1826, Ann. Sci. Nat., Paris, France, ser. 1, tome 7, p. 266.

*Hanzawaia concentrica* (Cushman) = *Truncatulina concentrica* Cushman, 1918, U. S. Geol. Surv., Bull. 676, p. 64, pl. 21, fig. 3.

*Poroeponides cribrorepandus* Asano and Uchio *in* Stach, 1951, Illustrated Catalogue of Japanese Tertiary smaller Foraminifera, pt. 14, p. 18, tfs. 134, 135.

*Quinqueloculina compta* Cushman, 1947, Cushman Lab. Foram. Res., Contr., v. 23, pt. 4, p. 87, pl. 19, fig. 2.

→

### Plate 3

Figure

1 *Siphotrochammina lobata* Saunders
  a, b Opposite sides, × 160
    Maximum diameter, 0.39 mm
2 *Tiphotrocha comprimata* (Cushman and Bronnimann)
  a, b Opposite sides, × 82
    Maximum diameter, 0.63 mm
3 *Ammonia beccarii* (Linné) variant
  a, b Opposite sides, × 215
    Maximum diameter, 0.24 mm
4 *Ammonia beccarii* (Linné) variant
  a, b Opposite sides of a corroded specimen, × 214
    Maximum diameter, 0.24 mm

All specimens are from Station 9.

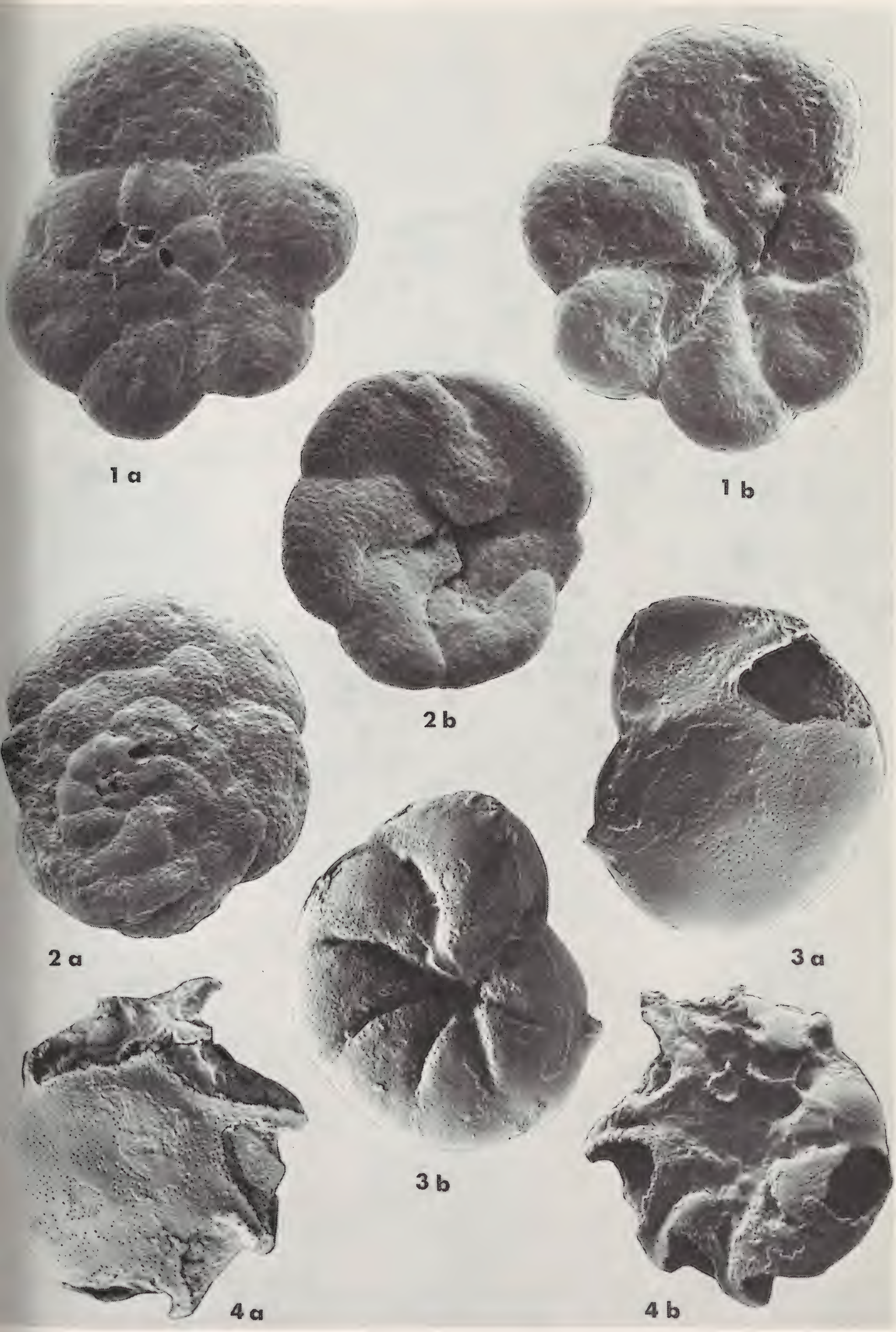


PLATE 3

*Quinqueloculina poeyana* d'Orbigny, 1839, *in* de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères", p. 191, pl. 11, figs. 25–27.

*Quinqueloculina seminulina* (Linné) = *Serpula seminulum* Linné, 1767, Syst. Nat., ed. 12, p. 1264.

*Quinqueloculina seminulina* (Linné) *jugosa* Cushman = *Quinqueloculina seminulina* (Linné) var. *jugosa* Cushman, 1944, Cushman Lab. Foram. Res., Spec. Publ. 12, p. 13, pl. 2, fig. 15.

*Rosalina floridana* (Cushman) = *Discorbis floridanus* Cushman, 1922, Carnegie Inst. Washington, Publ. no. 311, p. 39, pl. 5, figs. 11, 12.

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→

## Plate 4

*Miliammina beaufortensis*, new species

Figure

1 a-c Paratype
- a, c Side views, × 216
- b Edge view, × 216

Length, 0.27 mm; breadth, 0.16 mm; thickness, 0.13 mm

2 a-c Holotype
- a, c Side views, × 225
- b View of apertural area, × 757; aperture contains some extraneous material.

Length, 0.27 mm; breadth, 0.15 mm; thickness, 0.12 mm

3 a-c Paratype
- a, c Side views, × 214
- b Edge view, × 214

Length, 0.28 mm; breadth, 0.17 mm; thickness, 0.12 mm

All three specimens are from Station 9.

April 12, 1971

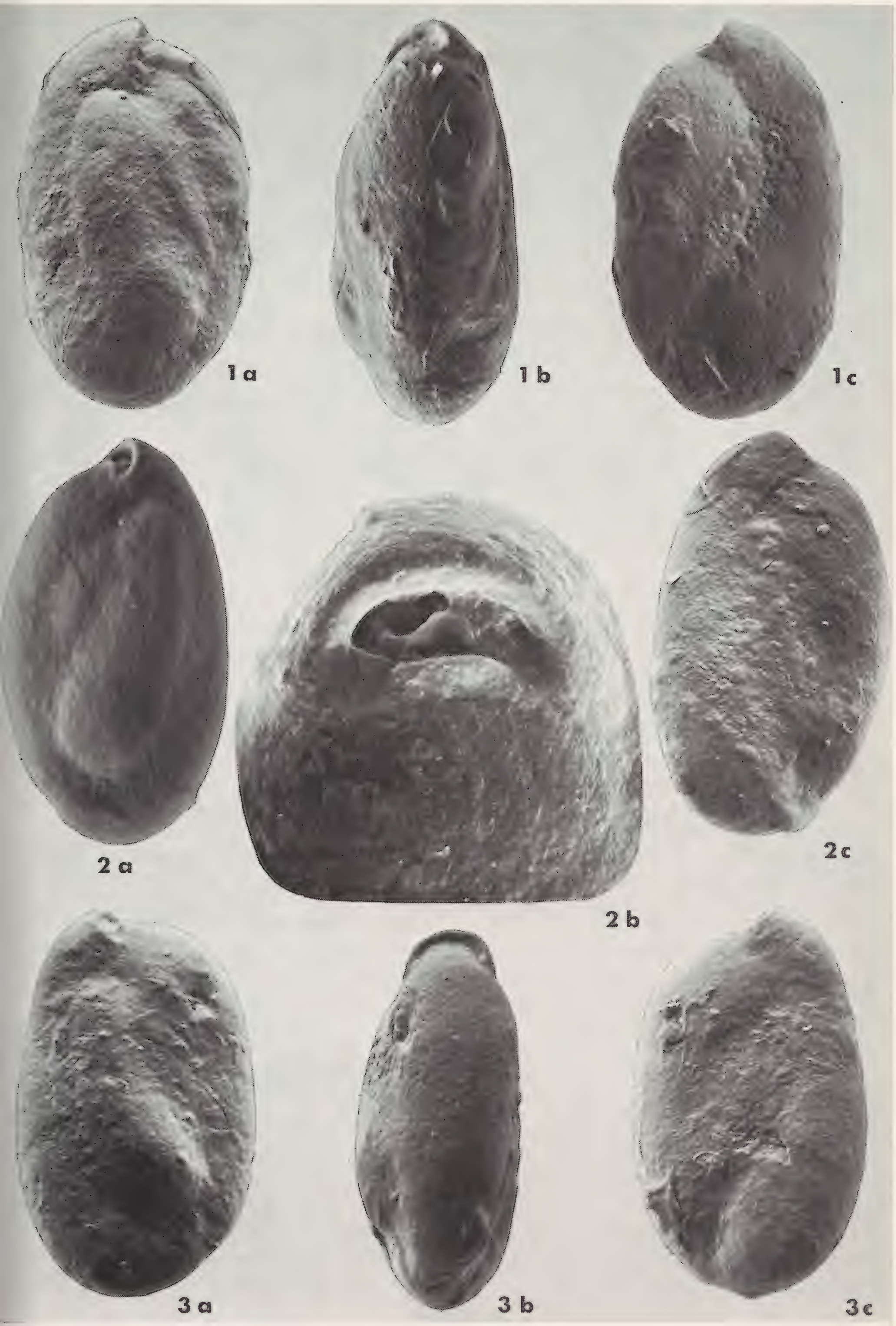


PLATE 4

# A NEW HOLOCENE SPECIES OF *ECHINOCYTHEREIS* (OSTRACODA)

MERVIN KONTROVITZ
*TULANE UNIVERSITY*

## I. Introduction

Several washed bottom samples, with an abundant ostracode fauna, were obtained from the Louisiana Continental Shelf southwest of the Mississippi River Delta. The samples were given to the writer for the purpose of studying the ostracode assemblages. A new species of the genus *Echinocythereis* Puri, 1953, was found and is described in this paper.

The genus *Echinocythereis* has been reported throughout most of the Cenozoic of the world and in Holocene sediments. Living specimens have been found only in marine waters and usually on the outer continental shelf or at greater depths (Puri, 1953; Van Morkhoven, 1963). The specimens in this study were recovered from water depths of 136 to 150 feet.

It was not possible to analyze the nature of the sediments because the samples were washed prior to their examination. Carsey (1950) indicated that the sediments in the area were a mixture of sand and mud.

## II. Acknowledgments

The writer wishes to thank Dr. Hubert C. Skinner, Department of Geology, Tulane University, who obtained the washed samples and made them available for this study. Dr. Ronald L. Parsley, of the same department, offered many useful suggestions concerned with the photographic techniques employed.

## III. Methods

The washed samples were dry-sieved and all material of 100 mesh (0.149 mm) or larger was examined for ostracode specimens. Juvenile and adult valves and fragments were retained for study.

Photographs were taken with a Wild M-5 microscope, Wild phototube, and an attached 35mm Nikon F camera. Photographed specimens were coated with silver nitrate or stained with ink by procedures as summarized by Sohn (1961).

Type specimens are deposited in the Henry V. Howe Collection, Louisiana State University.

Text figure 1. Central muscle scars, right valve (× 175).

## IV. Systematic Descriptions

Subclass Ostracoda Latreille, 1802
Order Podocopida Sars, 1865
Suborder Podocopina Sars, 1865
Superfamily Cytheracea Baird, 1850
Family Trachyleberididae
Sylvester-Bradley, 1948
Subfamily Echinocythereidinae
Hazel, 1967

Genus Echinocythereis Puri, 1953
Echinocythereis spinireticulata
Kontrovitz, n. sp.
Plate 1, Figures 1-3

Holotype: HVH 8595, left valve, female, length .95 mm; height .64 mm.

Paratypes: HVH 8596 (figured specimen), left valve, male, length .96 mm; height .61 mm.

HVH 8597 (figured specimen), female, right valve, length .99 mm; height .63 mm.

HVH 8598, male, right valve, length .99 mm; height .59 mm.

HVH 8599, juvenile, right valve, length .83 mm; height .53 mm.

Description: Subovate in lateral view, heavily calcified, large. Dorsal margin sinuous with a slight concavity behind eye tubercle, slight convexity at mid-length. Ventral margin with slight concavity just in front of mid-length, broadly convex behind mid-length. Anterior margin broadly rounded and denticulate below, acutely rounded and smooth from just above mid-height to eye tubercle. Posterior margin evenly rounded from venter to a point just above mid-height, acutely rounded above to posterior cardinal angle. Greatest length above mid-height.

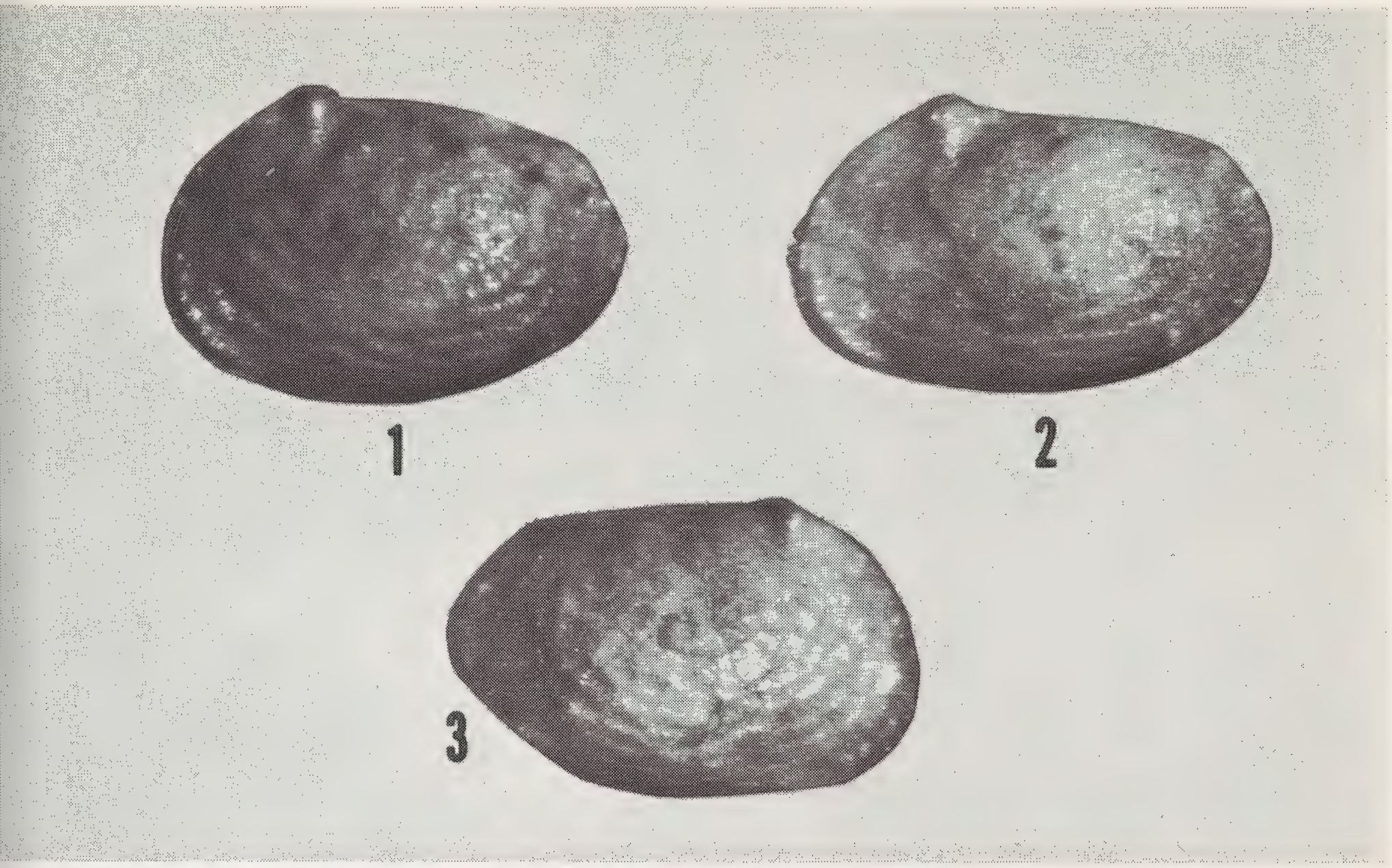


PLATE 1

*Echinocythereis spinireticulata* Kontrovitz, n. sp.

Figures

1. Holotype, HVH 8595
   Left valve, female; length .95 mm; height .64 mm (× 47).
2. Paratype, HVH 8596
   Left valve, male; length .96 mm; height .61 mm (× 47).
3. Paratype, HVH 8597
   Right valve, female; length .99 mm; height .63 mm (× 47).

---

Surface: Faintly reticulate, anterior, posterior, and ventral reticulations composed of minute, delicate spines. Central area with low faint reticulations composed of continuous ridges. Reticulations are elongate near margins and more equidimensional near center. Ornamentation centered about dorsomedial area of carapace and nearly concentric with anterior, posterior, and ventral margins. In poorly preserved specimens the minute spines are seen only as remnants and the rows are discontinuous. Juveniles are smooth at the central region but small spines are visible on the marginal areas. Adults have a row of slender spines immediately behind the denticulate anterior margin. Well preserved individuals have a long heavy spine projecting from the posterior ventrolateral convexity of the valve.

Dimorphism: Males appear to be longer because they are lower at the posterior cardinal angle.

Interior: Valves deep. Hinge, right valve, anterior tooth is high and pointed, followed by a deep elongate socket that merges with a smooth median groove. The median groove curves downward in front of posterior tooth. Posterior tooth is high, elongate, and follows the curve of the valve at the posterior cardinal angle. There is a faint appearance of lobation of the posterior tooth of some specimens but this may be due to poor preservation of those individuals. Hinge of left valve complementary with a deep anterior socket, low tooth that is part of a smooth median bar, and a deep curved posterior socket.

Inner lamella is moderately wide, widest at anterior, narrowest at venter, narrow but

distinct at posterior. Line of concrescence seems to be slightly removed from inner margin anteriorly and posteriorly. Selvage of right valve is prominent, removed from outer margin and flexed strongly upward just in front of mid-length at venter. There is a distinct groove outside of the selvage in the right valve. Selvage of the left valve is less distinct and close to the outer margin, corresponding to the groove of the right valve.

Radial pore canals difficult to observe because of the opaqueness of the valves. They seem to be simple and straight except at the upper anterior margin where they are slightly curved and may be false.

Central muscle scars, a vertical row of four; the top scar is suboval, next lower is subreniform, third from top is elongate as is the bottom scar. Second and fourth from top touch or nearly touch in front of second. Two frontal scars are subcircular.

Dimensions: Female right valves, length .97-1.00 mm; height .60-.64 mm; female left valves, length .96-.98 mm; height .63-.64 mm; male right valves, length 1.00-1.02 mm; height .59 mm; male left valves, length .96-1.04 mm; height .60-.63 mm.

Material: Forty-eight specimens, including 22 adult valves.

Remarks: The name of the species refers to the netlike ornamentation of spines; spini = thorny, reticulata = net. Eroded specimens do not retain the delicate spines but display the faint reticulation only.

This species differs from *E. jacksonensis* (Howe and Pyeatt, 1935) in being reticulate over the entire surface and having a higher posterior therefore appearing to be shorter. The original description of *E. jacksonensis* includes two forms, one larger than the other. The larger has anterior reticulations and only coarse spines from mid-length to the posterior. Krutak (1961) figured examples of *E. jacksonensis* with "tiny nodes which are aligned, tending to form hexagonal, pentameral, or angular patterns." The specimens he reported differ from *E. spinireticulata*, n. sp., in being smooth in the dorsal, posterior, and ventral areas. Muscle scars and length/height ratios are significantly different. (See text figure.)

*E. clarkana* (Ulrich and Bassler, 1904) is easily distinguished from this species by its coarsely reticulate surface with heavy spines at the juncture of the ridges, denticulate posterior margin, and larger size.

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April 12, 1971

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# TULANE STUDIES IN GEOLOGY AND PALEONTOLOGY

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DISTRIBUTION OF FORAMINIFERA ON THE NORTH CAROLINA CONTINENTAL SHELF

DETMAR SCHNITKER

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*IRA C. DARLING CENTER, WALPOLE, MAINE*[1]

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## I. Abstract

The quantitative distribution of one hundred and sixty-four species of foraminifera has been studied from eighty-six equal volume samples from the continental shelf of North Carolina. The area is strongly influenced by the Gulf Stream which follows the edge of the continental shelf north to Cape Hatteras from where it flows into the open ocean. A major faunal boundary exists at the latitude of Cape Hatteras, separating faunas which are characteristic for the central and northern Atlantic coasts of the U.S.

[1] Contribution No. 29 from the Ira C. Darling Center.

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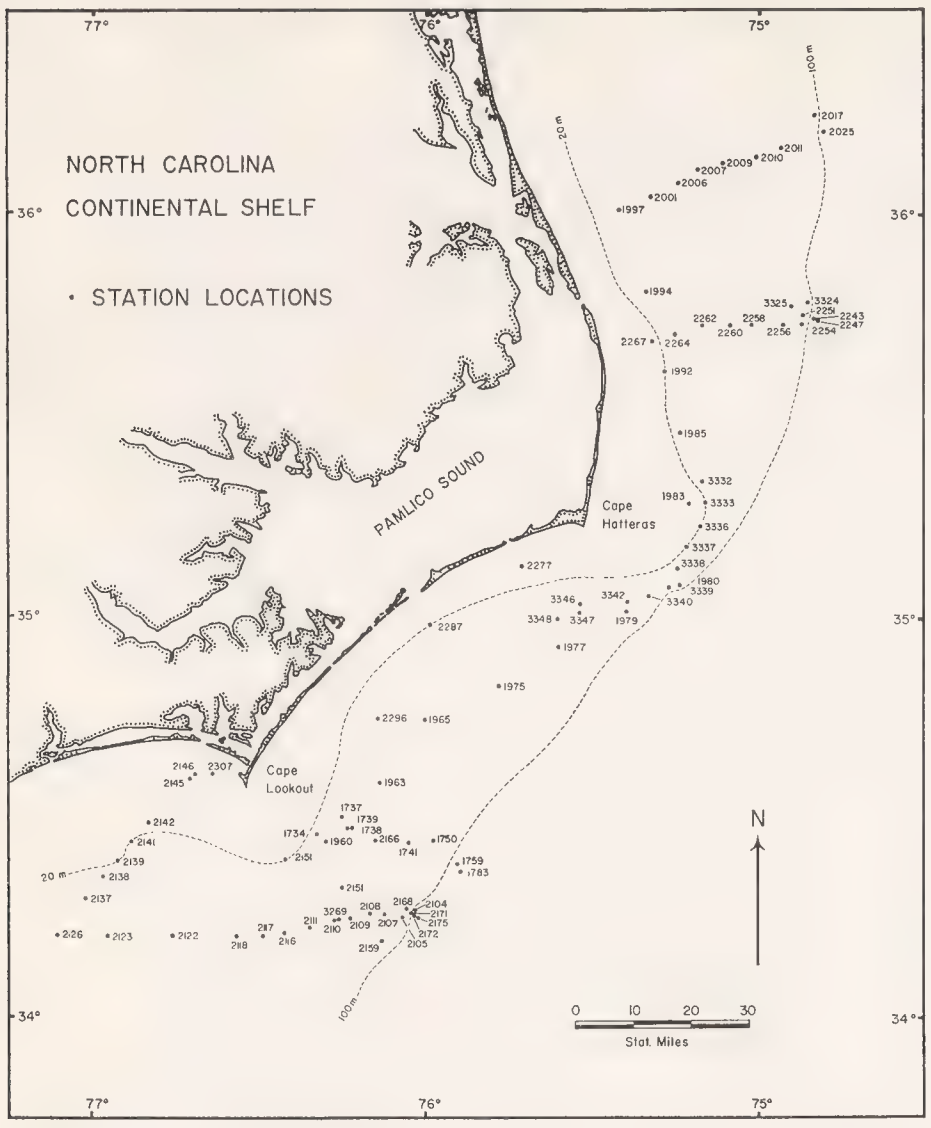


Figure 1. North Carolina Continental Shelf, Index to Sampling Stations

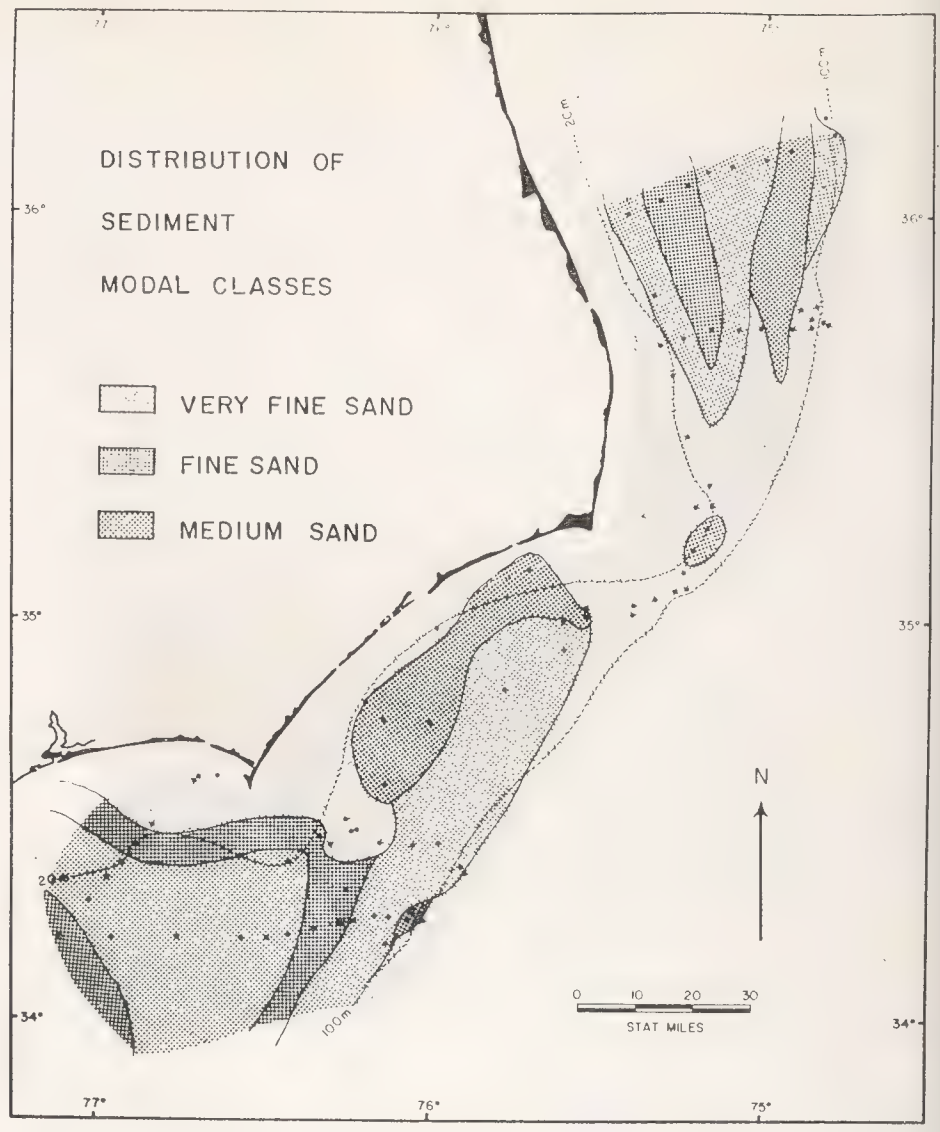


Figure 2. Distribution of sediment modal classes, as determined by the Ingram method (Ingram, 1965)

from faunas which are similar to those from Florida and the Gulf of Mexico. It is possible to distinguish a syn-thanatotope of the central shelf with a lower boundary of about sixty meters and a syn-thanatotope of the shelf edge. The total number of both, benthonic and planktonic specimens, increases with increasing depth. A relict fauna is present on the outer portions of the central shelf and shelf edge which indicates a rise in sea level of about sixty meters since the last Pleistocene glaciation stage. Faunal diversity is higher south of Cape Hatteras which signifies the stabilizing influence of the Gulf Stream in this area.

## II. Introduction

The purpose of this study is threefold: first, to inventory the foraminiferal faunas of the continental shelf of North Carolina; second, to determine quantitatively the composition of the foraminiferal populations; and third, to describe the distribution of these populations within the study area.

Interpretation of the faunal data attempts to characterize distinctive habitats and to relate particular distributions to the general oceanography of the area.

## Acknowledgments

This project was made possible by the Duke University Marine Laboratory through the use of the R/V *Eastward* in the Cooperative Oceanographic Program. This program is supported through NSF Grant G-17669 to Duke University. Sincere thanks are due Professor Joseph St. Jean, Jr. for his support during the initial phases of this project. The assistance of H. A. Curran and K. McKinney in collecting the samples is greatly appreciated. James Lacey arranged the computer analysis of the faunal data. The writer is greatly indebted to Professor William W. Hay for his guidance and aid which led to the completion of this study. Thanks are also extended to Professors H. R. Wanless, A. V. Carozzi, R. L. Langenheim and E. B. Small for their critical reading of the manuscript. The continued support and encouragement of Julia B. Schnitker is gratefully acknowledged.

## III. Area and Methods of Study

The study area is on the continental shelf off North Carolina between approximately 34° N and 36°30′ N Lat., and seaward to approximately the 100 meter contour line (fig. 1). The samples were collected on

several cruises of the R/V *Eastward* during the period of June 28 to November 8, 1965, at locations determined by Loran navigation and at depths determined by sonar sounding (Alpine PESR). An initial attempt to obtain bottom samples by a gravity coring device (Phleger, 1951) failed largely because of the compactness of the sandy substrate in most of the study area. Even additional weights and free fall trigger devices did not drive the corer more than 5 cm into the sand. Satisfactory samples were obtained, however, with a modified Van Veen grab. This sampler was provided with four large holes in the upper corners of the sides, so that the water could flow through the jaws when the grab was slowly lowered to the bottom. This minimized the effect of pushing a water mass ahead of the grab, which might sweep light, surficial material away from the grab at the moment of impact. The effectiveness of this modification was shown by capture of shrimp, still resting on the substrate. Further, the bottom-water interface was rarely disturbed, even where sediments were soft. The top of the grab was fitted with a door through which the samples were taken by pushing a short piece of plastic coring tube into the sediment. Thereafter the top centimeter of these sub-samples was cut off and stored in glass jars. For the preservation of live material, formaldehyde, neutralized and buffered with hexamethyleneamine and sodium bicarbonate, was added.

The sub-sampling method was tested by comparing two samples obtained by the gravity corer and the Van Veen grab off the docking facilities of the Duke Marine Laboratory. A chi-square test of the foraminiferal faunas indicated identity at the 95% confidence level.

In the laboratory, Rose Bengal was added to the samples approximately three hours before analysis to stain the protoplasm and

TABLE Ia PERCENTAGE DISTRIBUTION OF TOTAL BENTHONIC POPULATION (North of Cape Hatteras)

| STATION NUMBER | 1938 | 2267 | 1992 | 3333 | 3336 | 3337 | 2001 | 2007 | 3332 | 2006 | 1985 | 1997 | 2009 | 2264 | 1994 | 2260 | 2262 | 2010 | 2011 | 2258 | 2256 | 3325 | 3338 | 2254 | 2017 | 2251 | 3324 | 2243 | 2025 | 2247 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DEPTH IN METERS | 19 | 19 | 20 | 20 | 20 | 20 | 22 | 22 | 22 | 23 | 25 | 25 | 26 | 26 | 28 | 32 | 35 | 38 | 38 | 38 | 50 | 50 | 60 | 70 | 80 | 90 | 95 | 110 | 120 | 140 |
| *Ammobaculites dilatatus* | | | | | | | | | | | | | | | | | | | | | | | | | x | x | | | | x |
| *Ammodiscus catinus* | | | | | | | | | | | | | | | | | | x | 1 | | 3 | | | x | x | | x | | | |
| *Ammonia beccarii* | 2 | | | | 2 | | 5 | | | 2 | 1 | | 1 | 2 | 3 | 1 | | | | | | | | | | | | | | |
| *Amphistegina lessonii* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Articulina sagra* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Astacolus crepidulus* | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | | |
| *Asterigerina carinata* | | | | | | 6 | | | | | | | | | | | | | | | | | | | | | | | | |
| *Asterigerinata pulchella* | | | | | 2 | | 2 | 9 | 6 | 5 | 3 | 2 | 5 | 1 | 1 | | 3 | 1 | 1 | 3 | 1 | 1 | | x | | 1 | x | 1 | | 1 |
| *Astrononion stellatum* | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | | 1 | |
| *Bolivina alata* | | | | | | | | | | | | | | | | | | | | | | | | | x | | | | | x |
| *Bolivina albatrossi* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Bolivina lanceolata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Bolivina lowmani* | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | 1 | |
| *Bolivina pseudoplicata* | | | | | | | | | 3 | | 1 | | | | | | | x | | | | | | x | 1 | 1 | x | x | 1 | x |
| *Bolivina spathulata* | | | | | | | | | | | | | | | | | | | | | 1 | | | | x | x | | | | x |
| *Bolivina subaen. mexicana* | | | | | | | | | | | | | | | | | | | | | | | | | x | x | | x | 1 | 1 |
| *Buccella hannai* | 2 | 4 | | | 2 | | | | 8 | | 3 | 2 | 3 | 1 | 2 | 3 | 4 | 2 | | 3 | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Bulimina aculeata* | | | | | | | 1 | | | | | | 2 | 1 | | | | x | 5 | | | 3 | 1 | 2 | 2 | 2 | 2 | 1 | 1 | 2 |
| *Bulimina alazanensis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Bulimina marginata* | | | | | | | | | | | | | | | | | 1 | 2 | 1 | 1 | 1 | 4 | | 37 | 8 | 11 | 10 | 10 | 12 | 11 |
| *Buliminella elegantissima* | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | | |
| *Calcituba decorata* | | | | | 4 | | | | | | | | | | | | | | | | | | | | | 1 | | | | |
| *Cancris sagra* | 1 | | | | | | | | | | | | | | | | 1 | 2 | | 2 | 4 | 5 | 1 | 2 | 2 | 11 | 2 | 2 | 1 | 4 |
| *Caribeanella polystoma* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Cassidulina laevigata* | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x | x |
| *Cassidulina neocarinata* | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | 2 | x |
| *Cassidulinoides bradyi* | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x | 1 | 3 | x |
| *Chilostomella oolina* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Cibicides bradyi* | 2 | | | 11 | | | | | | 1 | | | 1 | | | 1 | 1 | 2 | 24 | 3 | 4 | 10 | 1 | 4 | 6 | 5 | 6 | 7 | 4 | 5 |
| *Cibicides pseudoungerianus* | | | | | 2 | | | | | | | | | | | | | | | 2 | | | | 10 | 8 | 5 | 9 | 6 | 9 | 6 |
| *Conicospirillina atlantica* | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | |
| *Cornuloculina inconstans* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Cyclogyra planorbis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Cyclogyra selseyensis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Cymbaloporetta atlantica* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Dentalina communis* | | | | | | | | | | | | | | | | | | | | | | | | x | | | x | x | 1 | x |
| *Discorbinella bertheloti* | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x |
| *Dyocibicides biserialis* | | | | | | | x | | | | | | | | | | | | | | | | | | | | | | | |
| *Edentostomina cultrata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Eggerella advena* | | | | | | | 2 | | | 8 | 3 | 4 | | | 2 | 2 | | 1 | 1 | 1 | x | | 1 | | | x | | x | | |
| *Elphidiella mexicana* | | | | | 4 | 6 | 2 | 3 | | | 1 | | 1 | 1 | | 6 | | 1 | 5 | 3 | 2 | | 1 | x | x | 3 | 1 | 6 | | 4 |
| *Elphidium advenum* | | | | | | | | | | | | | | 2 | | 1 | | | 4 | | | | | | | | | | | |
| *Elphidium clavatum* | 52 | 70 | 73 | 44 | 32 | 29 | 45 | 41 | 46 | 32 | 53 | 80 | 35 | 36 | 61 | 19 | 29 | 25 | 18 | 17 | 14 | 19 | 44 | 14 | 15 | 9 | 14 | 7 | 7 | 11 |
| *Elphidium incertum* | 3 | 2 | 3 | | 2 | | | | | 1 | 1 | | | 2 | 1 | 1 | 1 | | | | | 1 | 5 | | | x | x | | | x |
| *Elphidium subarcticum* | 4 | 4 | 3 | | | | 1 | | 4 | 1 | 8 | | 8 | 2 | 5 | 5 | | 8 | 10 | 3 | 2 | 4 | 1 | 5 | 5 | 7 | 8 | 8 | 2 | 3 |
| *Eponides antillarum* | | | | | | | | | | | | | | | | | | x | | | | | | | x | | | | | x |

aid recognition of specimens alive at the time of sampling (Walton, 1952).

Each sample, containing about 11.5 cubic centimeters of sediment was split three times, using an Otto microsplit, resulting in a sample of slightly more than one cubic centimeter. The volume of this split was measured as accurately as possible for determination of absolute abundance. The samples were sieved on a 160 mesh screen (0.1 mm average openings), and all foraminifera were picked from the wet residues. Stained and unstained specimens were placed on separate slides and later the number of foraminifera found in each sample was recalculated for a sample volume of exactly one cubic centimeter. Where fewer than 400 specimens were found per split, previously unused fractions of the split were counted out, to procure at least this number of individuals following the suggestions of Wright (1964).

The abundance of each species at any station is expressed in percent of the total benthonic population. All percentage values were rounded off to the nearest 1%.

The sediments were studied and described according to the semiquantitative microscopic inspection technique described by Ingram (1965). This relatively rapid method permits definition of sediment distribution patterns as well as by conventional sieve methods.

## IV. Previous Work

The foraminifera of coastal North Carolina have received little attention. In his

TABLE Ia (continued)

| STATION NUMBER | 1938 | 2267 | 1992 | 3333 | 3336 | 3337 | 2001 | 2007 | 3332 | 2006 | 1985 | 1997 | 2009 | 2264 | 1994 | 2260 | 2262 | 2010 | 2011 | 2258 | 2256 | 3325 | 3338 | 2254 | 2017 | 2251 | 3324 | 2243 | 2025 | 2247 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DEPTH IN METERS | 19 | 19 | 20 | 20 | 20 | 20 | 22 | 22 | 22 | 23 | 25 | 25 | 26 | 26 | 28 | 32 | 35 | 38 | 38 | 38 | 50 | 50 | 60 | 70 | 80 | 90 | 95 | 110 | 120 | 140 |
| *Eponides tumidulus* | | | | | | | | | | | | | | | | | | | | | | | | | x | x | | | 1 | x |
| *Eponides repandus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Fischerinella dubia* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Fissurina lacunata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Fissurina lucida* | | | | | | | | | | | | | | | | | | x | | | | | | | | x | | | | x |
| *Fissurina stewartii* | | | | | | | | | | | | | | | 1 | | | | | | | | | | | x | | x | x | x |
| *Florilus atlanticus* | 3 | | | 22 | 4 | | 1 | | | 1 | 3 | | 1 | 1 | | | | 2 | 1 | 1 | | 1 | 1 | 1 | 1 | 1 | 1 | x | 1 | 1 |
| *Florilus auriculus* | | | | | | | | | | | | | | | | | | | | | | | 1 | x | | x | x | | 1 | |
| *Fursenkoina fusiformis* | | | | | | | | | | | | | 1 | | 3 | | 1 | x | | | 17 | | | x | 2 | 1 | | | 2 | |
| *Fursenkoina punctata* | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | | x |
| *Glabratella lauriei* | | | | | | | | | | 2 | | | | | | | | | | | | | | | | | | | | |
| *Globobulimina auriculata* | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | x | x |
| *Guttulina caribea* | | 1 | | | | | 2 | 3 | | 1 | 1 | | 1 | 1 | | | 1 | 1 | | | | | | | | | x | x | | |
| *Guttulina lactea* | 2 | 2 | 2 | | | | 4 | | 3 | 6 | 2 | 2 | 10 | 3 | | 4 | | 5 | 4 | 3 | | 1 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 1 |
| *Guttulina pulchella* | | | | | | | x | | | 1 | 1 | | 1 | | | 1 | | 1 | | | | | | | | | x | | x | |
| *Gyroidina orbicularis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x |
| *Hanzawaia concentrica* | 12 | 8 | 10 | | 11 | | 17 | 12 | | 14 | 11 | | 9 | 9 | 6 | 18 | 21 | 16 | 2 | 7 | 7 | 4 | 6 | 1 | x | x | 1 | x | 1 | 1 |
| *Haplophragmoides canariensis* | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | x | |
| *Höglundina elegans* | | | | | | | | | | | | | | | | | | | | | | | | | | x | | x | | |
| *Islandiella subglobosa* | | | | | | | | | | | | | | | | | | 2 | 2 | 1 | 2 | | 1 | 12 | 18 | 22 | 18 | 24 | 15 | 19 |
| *Lagena acuticosta* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x |
| *Lagena laevis* | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | |
| *Lagena striata* | | | | | | | | | | | | | | | | | | | | | | | 1 | | x | | x | | x | x |
| *Lagena tenuis* | | | | | | | | | | | | | | | | | | x | | | | | | | x | | | | x | |
| *Lenticulina orbicularis* | | | | | | 6 | | | | | | | | | | | | | | | | | | 12 | 5 | 6 | 4 | 4 | 10 | 2 |
| *Marginulina advena* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Marginulina bachei* | | | | | | | | | | | | | | | | | | | | | | | | 2 | 2 | 1 | 1 | 1 | 3 | x |
| *Marginulina villa* | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | |
| *Melonis pompilioides* | | | | | | | | | | | | | | | | | | | | | | | | | 1 | 1 | 1 | | x | 1 |
| *Miliolinella circularis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Miliolinella fichteliana* | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | |
| *Mississippina concentrica* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Neoconorbina terquemi* | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | |
| *Nodobacullariella atlantica* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Nodosaria catesbyi* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x |
| *Nonion grateloupi* | | | | | | | | | | | | | | | | | | | | | 1 | | | | x | x | | x | x | |
| *Nonionella turgida* | | | | | | | x | | | | 1 | | | | | | | x | | | 2 | | | | 1 | x | | x | 2 | x |
| *Oolina melo* | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | x | |
| *Patellina corrugata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Peneroplis discoideus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Peneroplis proteus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Placopsilina confusa* | | | | | 7 | 12 | | | | | | | | | | | | | 1 | | | | | | | | | | | |
| *Planorbulina mediterranensis* | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | |
| *Planulina ariminensis* | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | | | x | x |
| *Planulina exorna* | 1 | | | | | | x | | | | 1 | 4 | 4 | 1 | 1 | | 5 | 5 | 2 | 13 | 2 | 1 | 1 | 1 | 1 | x | 1 | x | 1 | 1 |
| *Planulina ornata* | 7 | 2 | 2 | | 7 | | 2 | 3 | 22 | 5 | 3 | 2 | 7 | 1 | 1 | 13 | 4 | 6 | 6 | 9 | 4 | 4 | 3 | 5 | 3 | 3 | 5 | 3 | 1 | 4 |
| *Pullenia quinqueloba* | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | | |
| *Pyrgo denticulata* | | | | | | | | | | | | | | | | | | | | 1 | | | | 1 | 1 | x | 1 | | x | x |
| *Pyrgo oblonga* | | | | | | | | | | | | | | | | | | | | 1 | 1 | | | 1 | 1 | 2 | x | 1 | 1 | 2 |
| *Pyrgo serrata* | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | | | |
| *Pyrgo subsphaerica* | | | | | | | | | | | | | | | | | | | 1 | | | | | x | x | | x | | | |

work on the foraminifera of the Atlantic Ocean, Cushman (1918 to 1931) included material collected in this area. Cushman's contribution, however, was primarily taxonomic, although he discussed general distribution and occurrence of species. In 1936, Hadley briefly discussed recent foraminifera from near Beaufort, N. C. Cushman (1947) described seventeen new species and varieties from the Atlantic Coast between Cape Hatteras and southern Florida. In 1953, Miller investigated the foraminiferal distribution in Mason Inlet, N. C., south of the present study area. Most recently, Wilcoxon (1964) studied foraminiferal distribution off the southern Atlantic Coast between the Florida Straits and Cape Hatteras. He recognized three faunal depth zones on the shelf: Inner shelf, 1–15 meters; middle shelf, 15–61 meters; outer shelf—upper continental slope, 61–183 meters. More detailed papers have been published on the foraminifera from off Portsmouth, N. H. (Phleger, 1952, and Parker, 1952) and from the shelf from the Gulf of Maine to Maryland (Parker, 1948).

## V. Description of Area

The continental shelf off North Carolina is the submarine extension of the coastal plain and is underlain by gently eastward dipping Upper Cretaceous and Cenozoic strata. At the coastline it is bordered by a series of long narrow offshore bars which protect extensive lagoons and estuaries. The shelf break to the east occurs generally at depths of 60–80 meters. The shelf is a flat

TABLE Ia (continued)

| STATION NUMBER | 1938 | 2267 | 1992 | 3333 | 3336 | 3337 | 2001 | 2007 | 3332 | 2006 | 1985 | 1997 | 2009 | 2264 | 1994 | 2260 | 2262 | 2010 | 2011 | 2258 | 2256 | 3325 | 3338 | 2254 | 2017 | 2251 | 3324 | 2243 | 2025 | 2247 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DEPTH IN METERS | 19 | 19 | 20 | 20 | 20 | 20 | 22 | 22 | 22 | 23 | 25 | 25 | 26 | 26 | 28 | 32 | 35 | 38 | 38 | 38 | 50 | 50 | 60 | 70 | 80 | 90 | 95 | 110 | 120 | 140 |
| *Quinqueloculina bicostata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Quinqueloculina bosciana* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Quinqueloculina compta* | | | | | | | x | | | | 1 | | | | | | | | | | | | | | | | | | | |
| *Quinqueloculina jugosa* | 4 | | | | 2 | | 1 | | | 1 | 1 | | | | 1 | | | 1 | 4 | 1 | | | | | 1 | x | | x | 1 | x |
| *Quinqueloculina lamarckiana* | | | | | | | | | | | | 3 | | | | | 1 | | | | | | | | | | x | x | | |
| *Quinqueloculina poeyana* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Quinqueloculina polygona* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Quinqueloculina seminula* | 2 | 2 | | | 12 | 18 | 8 | 9 | | 3 | | | 1 | 9 | 4 | 10 | 9 | 10 | 8 | 6 | 3 | 1 | | x | 1 | | x | | x) | x |
| *Rectobolivina advena* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Reophax atlantica* | 1 | 2 | 6 | | | 20 | | | 16 | 1 | 3 | 4 | | 20 | 7 | 11 | 6 | 1 | | 11 | 14 | 17 | 2 | 6 | 2 | 2 | 2 | 2 | 1 | 2 |
| *Reophax fusiformis* | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | | | |
| *Reophax scorpiurus* | 1 | | 1 | | | | 1 | | 3 | | 1 | | | | | | 1 | | | | | | | 1 | | x | x | x | x | |
| *Reussella atlantica* | | | | | 2 | 6 | | | | | | | | | | 22 | | | | | | | | x | | | | x | | |
| *Robertinoides normani* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x |
| *Rosalina floridana* | | | | | | | | | | | | | | | | | | | | | | | 1 | x | 1 | x | | | | 1 |
| *Rosalina floridensis* | | | | | | | | | | | | | | | | | | | 2 | | | | 1 | | | | | | | x |
| *Rosalina globularis* | | 2 | | | 2 | | | | | | 1 | | | | | 1 | | | | | 1 | 3 | 7 | 1 | 1 | x | x | 1 | x | 1 |
| *Rosalina rugosa* | | | | | 2 | | | | | | | | | | | | | 1 | | 1 | 4 | 3 | 3 | 4 | 3 | 2 | 5 | 4 | 1 | 3 |
| *Sagrina pulchella* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Scuturoris procera* | | | | | | | x | | | | 1 | | | | | 1 | | | 2 | 2 | | | 1 | x | | | | | x | x |
| *Sigmoilina antillarum* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Sigmoilina tenuis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Siphonaptera horrida* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Siphonaptera sabulosa* | | | | | | | | | | | | | | | | | | x | | | | | | x | | | x | | | |
| *Siphonina pulchra* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Siphotextularia curta* | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | | |
| *Siphotextularia rolshauseni* | | | | | | | | | | | | | | | | | | | | | | | | | x | | x | | | |
| *Sphaeroidina bulloides* | | | | | | | | | | | | | | | | | | | | | | | 1 | x | | | | | 1 | x |
| *Spiroloculina atlantica* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Spiroloculina depressa* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Spiroplectammina floridana* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Stainforthia complanata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Stetsoina minuta* | | | | | | | | | | | | | | | | | | | | | 1 | | | 1 | 2 | 1 | 1 | 1 | 3 | 2 |
| *Stilostomella antillea* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Textularia candeiana* | 1 | | | | | | | | | | | | | | | | | 2 | | | | | | 1 | | | x | | | x |
| *Textularia conica* | 1 | | | | | | | | | | | | | | | | | x | | 1 | | | 1 | | | x | x | x | 1 | x |
| *Textularia pseudotrochus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Textularia truncata* | | | | | | 6 | | | | | | | | 1 | | | | x | | 1 | | | | | | x | | | x | |
| *Textulariella barrettii* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Trifarina angulosa* | | | | | | | | | | | | | | | | | | | | | 2 | | | 2 | 3 | 3 | 3 | 3 | 4 | 4 |
| *Trifarina bradyi* | | | | | | | | | | | | | | | | | | | | | | | | x | | x | | | | x |
| *Triloculina tricarinata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Triloculina trigonula* | 1 | | | | | | | | | | | | | | | | | 1 | 1 | | x | | | | x | | x | x | | x |
| *Trochammina advena* | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | | |
| *Trochammina squamata* | | | | | | | | | | | | | | | | | | | | | 1 | | | x | | | | | | x |
| *Trovhamminula lobata* | | 1 | | | | | | | | | | | 3 | | 1 | | | x | | 1 | 2 | 1 | 1 | x | 1 | x | | x | | x |
| *Uvigerina auberiana* | | | | | | | | | | | | | | | | | | | | | | | 1 | | | x | x | x | x | x |
| *Uvigerina peregrina* | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | | | x |
| *Valvulineria laevigata* | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | |
| *Webbinella concava* | | | 3 | | | 6 | 5 | 12 | | 10 | 1 | | 5 | 8 | 3 | 2 | 7 | 2 | 4 | 1 | | 9 | | 2 | | | x | | | |
| *Wiesnerella auriculata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

plain, 50 to 80 statute miles wide, which narrows to 17 statute miles off Cape Hatteras. The average slope, from the coastline to 70 meters depth ranges from 4.5 to 9.5 feet/mile with the least inclination on the central shelf. Slopes are considerably steeper at the shelf edge.

The water masses overlying the shelf of the study area, the Virginian Coastal water and Carolinian Coastal water of Bumpus & Pierce (1955), are bounded to seaward by the Gulf Stream. The Virginian Coastal water is formed by mixing of slowly southward drifting oceanic water, land runoff and indrafts of slope water (Bigelow and Sears, 1935). The Carolinian Coastal water is formed by Gulf Stream water and land runoff, but runoff contribution is minimal. Gulf Stream water broadly invades the southern shelf frequently. The Virginian and Carolinian Coastal water masses connect around Cape Hatteras only rarely under the influence of northeasterly storms between November to May (Bumpus and Pierce, 1955).

Bottom temperatures north of Cape Hatteras range from less than 9°C near shore to 16°C near the edge of the shelf during the winter. In May, temperature near shore and at the edge of the shelf is 18°C, but is 16°C at the bottom of the central shelf (Bumpus and Pierce, 1955). Maximum surface temperatures during the summer reach 25°–26°C (Fuglister, 1947). South of Cape Hatteras, in Raleigh Bay, winter bottom temperatures may be as cold as to the north, because of an influx of Virginian Coastal water. South of Cape Lookout this influence is no longer present and bottom temperatures in January range from 10°C near shore to 19°C at the shelf edge (Bumpus and Pierce, 1955). Summer surface temperatures reach 27°C (Fuglister, 1947).

Bottom salinities in the Virginian Coastal water range from 31.5‰ near shore to 36‰ near the shelf edge during winter and from 31‰ to 35.5‰ during spring. Carolinian Coastal water is generally more saline, because of mixing with Gulf Stream water and lesser runoff. During the winter, the water in Raleigh Bay may be of reduced salinity because of influx of Virginian Coastal water. Bottom water salinity normally ranges be-

TABLE I b PERCENTAGE DISTRIBUTION OF TOTAL BENTHONIC POPULATION (South of Cape Hatteras)

| STATION NUMBER | 2145 | 2146 | 2142 | 2307 | 2141 | 2277 | 2139 | 2151 | 2287 | 2137 | 2138 | 2110 | 2127 | 1734 | 1965 | 2116 | 2118 | 2122 | 2123 | 3348 | 1977 | 2117 | 2156 | 2111 | 3269 | 1960 | 2296 | 1963 | 3346 | 3347 | 1737 | 1738 | 1739 | 2109 | 1741 | 2166 | 1975 | 2159 | 3342 | 2108 | 1979 | 2107 | 3340 | 2105 | 2168 | 1750 | 1980 | 3339 | 2171 | 1759 | 2172 | 2104 | 2175 | 1783 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DEPTH IN METERS | 12 | 12 | 15 | 16 | 17 | 18 | 20 | 20 | 20 | 22 | 22 | 23 | 23 | 24 | 25 | 25 | 25 | 25 | 25 | 25 | 26 | 26 | 26 | 28 | 28 | 29 | 29 | 30 | 30 | 30 | 33 | 33 | 33 | 36 | 41 | 42 | 44 | 50 | 50 | 52 | 55 | 57 | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 122 | 125 | 140 | 155 | 159 |
| *Ammobaculites dilatatus* | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | 1 | 4 | 1 | x | | | | | | | | | | | | | | | x | | | | | x | | x |
| *Ammodiscus catinus* | | | | | | | | | | x | | | | | | x | | x | x | | | x | | | | | | | 1 | | | | | | | | | | 1 | | | | | x | x | | | | | | | | |
| *Ammonia beccarii* | 10 | 4 | | 8 | | 2 | 1 | 3 | 2 | | 2 | 7 | | 1 | | 4 | 1 | | | | 2 | 3 | 1 | 3 | 2 | 4 | | | 4 | 1 | x | 2 | 1 | 6 | 2 | 2 | | 6 | | 4 | | 3 | x | 2 | 2 | 4 | 1 | x | 2 | 3 | | x | 1 | 3 |
| *Amphistegina lessonii* | | | | | | | | | | | | | | | | | | | | | | | | | 2 | | | | | | | | | | 1 | | | | | 8 | 16 | 2 | x | 1 | 3 | 4 | 1 | 1 | 1 | 1 | | | |
| *Articulina sagra* | | | | | | | 1 | | | | | | | | | x | x | | | | | | | | | 1 | | 2 | | | 1 | 1 | 1 | x | 1 | 1 | 1 | | | | x | | | x | | | | 1 | 1 | x | x |
| *Astacolus crepidulus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | 2 | x | |
| *Asterigerina carinata* | | | 2 | x | 3 | | 2 | | 2 | 8 | 5 | 10 | 8 | 1 | 12 | 12 | 10 | 7 | 9 | | 2 | 10 | 2 | 6 | 2 | 1 | 4 | 3 | | 3 | 2 | 2 | 2 | 10 | 6 | 4 | 5 | 8 | | 5 | 1 | 6 | | 1 | 2 | 3 | | 7 | 3 | 3 | x | x | 2 | 2 |
| *Asterigerinata pulchella* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 | | | x | | | 1 | | | | 2 | | 1 | | 2 | | | | 2 | x | | | | x | | |
| *Astrononion stellatum* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | |
| *Bolivina alata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | |
| *Bolivina albatrossi* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x |
| *Bolivina lanceolata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Bolivina lowmani* | 1 | | | | 1 | | | | | x | | | | | | 1 | | x | | | | | | | | x | | | | | | x | | | | | | | | x | | | | x | 1 | | | 1 | 1 | 2 | x | x |
| *Bolivina pseudoplicata* | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | x | | | | | | | | x | | 1 | | |
| *Bolivina spathulata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | |
| *Bolivina subaen. mexicana* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | 1 | 1 | x |
| *Buccella hannai* | 3 | 1 | | 1 | | | 1 | 2 | x | 1 | | | | 1 | | 1 | 1 | 1 | x | | 1 | 1 | 1 | 1 | | 1 | 2 | 3 | 1 | 1 | 1 | 1 | 1 | x | 4 | 2 | 1 | | 4 | 2 | x | | 1 | | 2 | x | x | x | 1 | 1 | | x | | 1 |
| *Bulimina aculeata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | | | x | | | | | | x |
| *Bulimina alazanensis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x |
| *Bulimina marginata* | | | | | | | | | | | | 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | x | | 1 | x | | x | x | 1 | x |
| *Buliminella elegantissima* | x | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | |
| *Calcituba decorata* | | | 2 | | | | 7 | | | 1 | | | 10 | | 4 | 1 | 1 | 1 | 4 | | | | | | 22 | | 1 | | | 1 | | | | 1 | | | | | | | | | 1 | | | | | | 1 | | | | |
| *Cancris sagra* | | | | | | | | | | | | | | | | | | | | | | | | | | x | | 1 | | | | | 1 | | | | | | | | | | | | | | | | | | | | |
| *Caribeanella polystoma* | | | 2 | | | | 6 | | | 9 | 3 | | 7 | | | 1 | 4 | 1 | 3 | | 1 | | 10 | | | 2 | 3 | | | | | | | | 4 | | 1 | | | 1 | x | | x | | | 7 | 5 | 1 | | | x | 3 | 4 | 1 | |
| *Cassidulina laevigata* | | | | | | | | | | | | | | | | x | x | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | | | x | x | 1 | x | x |
| *Cassidulina neocarinata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | 1 | 1 | 4 | 4 |
| *Cassidulinoides bradyi* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | | | | | | | | | | | | | | | | | | | | x | | |
| *Chilostomella oolina* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | x |
| *Cibicides bradyi* | 2 | | | | | | 1 | | | 3 | 6 | 2 | 2 | | | 3 | 1 | 1 | 1 | | | 2 | 2 | 3 | | 3 | | 1 | | 1 | 5 | 3 | 2 | 2 | 4 | 11 | | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 1 | | x | 2 | 1 | 2 | 3 |
| *Cibicides pseudoungerianus* | 1 | | | | | | | | | | 1 | | x | | | x | x | | | | | | | | | | | | | | 1 | x | 1 | x | | | | | | | x | x | | 2 | | | 1 | 7 | 6 | 1 | 2 | 1 | x | 2 | 2 |
| *Conicospirillina atlantica* | | | | | | | | | | x | | | | | | | | | x | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | x | |
| *Cornuloculina inconstans* | | | | | | | | | | | | | | | | | x | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | |
| *Cyclogyra planorbis* | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | | | | | | | | | | | | | | | | | | | | | | | | x | 1 | | |
| *Cyclogyra selseyensis* | | | | | | | | | 2 | | | | | | | x | x | | | | | | | | | | | | | | | | | x | | | | | | | x | | 1 | | | | | | | | x | | | |
| *Cymbaloporetta atlantica* | | | | | | | | | | | | | | | | | x | | | | | | | | | | | | | | | | | | | | | | | | | x | | | | | | | | | | 1 | x | x | |
| *Dentalina communis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | x | | | | | | | | x | x | | |
| *Discorbinella bertheloti* | | | | | | | | | | x | | | | | | x | | | 1 | | | | | | | | | | | | | | x | | | 1 | | | | x | | x | | | | | | | | | 1 | 1 | 1 | 1 |
| *Dyocibicides biserialis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | | | | | | | x | | | | | | | | | x | | x | |
| *Edentostomina cultrata* | | | | | | | | | | | | | | | | | x | | | | | | | | | | | x | | | | | | | | | | | | | | | | | | | | | | | x | x | | |
| *Eggerella advena* | | | | | | | | | | x | | | | | | 1 | | | | | | | | | | x | | | | | | | x | | | 1 | | | | 2 | 1 | | | | | | | x | 1 | | x | x | | x | |
| *Elphidiella mexicana* | 7 | 2 | 2 | | 3 | | 1 | 1 | | 2 | 7 | | x | | | 1 | 1 | 1 | 1 | | 1 | 1 | | 1 | 2 | 3 | | 1 | | | 3 | x | 3 | 1 | 2 | 3 | 3 | | | 1 | 5 | | | 4 | 1 | 5 | x | | | 1 | | 2 | 1 |
| *Elphidium advenum* | | | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | 2 | | | | | | | 1 | | | | | | | | | | | | | | | | | | |
| *Elphidium clavatum* | 27 | 65 | 5 | 35 | | 9 | 1 | 10 | 13 | 2 | x | 11 | 1 | 7 | | 11 | 8 | 1 | | 7 | 3 | 9 | 15 | 7 | 14 | 5 | 2 | 1 | 66 | 11 | 2 | 26 | 1 | 21 | 19 | 7 | 3 | 21 | 72 | 12 | 15 | 11 | 25 | 17 | 8 | 6 | 11 | 9 | 11 | 16 | | 2 | 1 | 11 |
| *Elphidium incertum* | | | | 3 | 1 | 2 | | | | 1 | x | | x | | 1 | 1 | x | | 1 | | | 1 | | 1 | | 1 | | 1 | | 1 | x | x | | x | | 1 | 1 | 1 | 1 | 3 | | | 1 | 2 | 3 | | 1 | | 2 | 3 | x | x |
| *Elphidium subarcticum* | | | | 7 | | | | | | | | | | | | 1 | | | | | | | | | | 3 | | | 9 | 4 | 2 | 1 | 2 | x | | 1 | 1 | 1 | 9 | 1 | | | 2 | | 2 | x | 2 | 2 | | | x | x | x | 1 |
| *Eponides antillarum* | | | | | | | | | | | | 1 | | 1 | | 1 | x | | | 2 | 7 | | | 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

tween 35‰ and 36‰ (Bumpus and Pierce, 1955).

Stetson (1938), Gorsline (1963), Uchupi (1963), and Emery (1966), in the course of large scale surveys of this area have recognized two broad subdivisions within the sediments: a narrow band of modern sediments near the shoreline to a depth of about 20 meters, and relict sediments, which cover the middle and outer portions of the shelf (Emery, 1966).

Figure 2 shows the distribution of the sediment types. The band of very fine grained, near shore sediment is readily apparent. Off Cape Hatteras, however, very fine grained sand has spread across the entire shelf. Off Cape Lookout the very fine grained sand extends far onto the shelf, but does not completely cover it. On the central shelf, fine and medium grained sand dominate. Along the shelf edge very fine grained sand also occurs, and much of it has a bimodal size distribution. Medium or coarse grained sand is present here in amounts of as much as 20%.

Calcium carbonate generally comprises less than 5% of the shelf sediments north of Cape Hatteras. South of the Cape, the amount of calcium carbonate increases markedly. Occurring here in the form of shell fragments and oölites, it may make up from less than 5% of the sediment on the inner shelf to more than 25% on the outer shelf. On the central and outer shelf south of Cape Hatteras and especially south of Cape Lookout, much of the carbonate fraction of the sediment shows signs of alteration in the form of brown and yellow iron staining, glauconitization and phosphatization.

## VI. Distribution of Foraminifera

The total abundance of foraminifera per unit sediment has been commonly expressed as the number of specimens per gram of sediment and this has been called the foraminiferal number by Schott (1935). In this

TABLE I b (continued)

| STATION NUMBER | 2145 | 2146 | 2142 | 2307 | 2141 | 2277 | 2139 | 2151 | 2287 | 2137 | 2138 | 2110 | 2127 | 1734 | 1965 | 2116 | 2118 | 2122 | 2123 | 3348 | 1977 | 2117 | 2156 | 2111 | 3269 | 1960 | 2296 | 1963 | 3346 | 3347 | 1737 | 1738 | 1739 | 2109 | 1741 | 2166 | 1975 | 2159 | 3342 | 2108 | 1979 | 2107 | 3340 | 2105 | 2168 | 1750 | 1980 | 3339 | 2171 | 1759 | 2172 | 2104 | 2175 | 1783 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DEPTH IN METERS | 12 | 12 | 15 | 16 | 17 | 18 | 20 | 20 | 20 | 22 | 22 | 23 | 23 | 24 | 25 | 25 | 25 | 25 | 25 | 25 | 26 | 26 | 26 | 28 | 28 | 29 | 29 | 30 | 30 | 30 | 33 | 33 | 33 | 36 | 41 | 42 | 44 | 50 | 50 | 52 | 55 | 57 | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 122 | 125 | 140 | 155 | 159 |
| *Eponides tumidulus* | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | x | x | | | | | | | | | | x | | | | | x | x | 1 | | x | x | 1 | x |
| *Eponides repandus* | | | | | | | | | | | | | | | | | | | | 2 | | | | | | | | | | 1 | | | | | | | | | | | | | | 3 | | | | | x | 3 | | | | | |
| *Fischerinella dubia* | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | | | | | | | | | | | | | | | | | | | | | | | x | | | | |
| *Fissurina lacunata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | |
| *Fissurina lucida* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | |
| *Fissurina stewartii* | | | | | | | | | | | | | | | 1 | x | | | | | | | | 1 | | x | | | | | | | | | | | | | | | | | | | | | x | | | | | x | | | |
| *Florilus atlanticus* | | 1 | | 2 | | | 1 | | 5 | 1 | | | 1 | 2 | 1 | 3 | 2 | x | 1 | 2 | | 1 | | 2 | | | | 3 | 3 | 2 | 6 | 9 | 4 | 2 | 6 | 5 | | | 2 | 4 | 2 | 2 | 1 | 2 | 2 | 2 | 3 | 1 | | 3 | 1 | 2 | 1 | 3 |
| *Florilus auriculus* | | | | | | | | | | | x | | | | 1 | | | | 1 | 2 | 1 | | 1 | | | 1 | | | 1 | 1 | 1 | 2 | 1 | x | | | | | | x | x | | | | 2 | x | x | | | 2 | x | x | 1 |
| *Fursenkoina fusiformis* | | | | | | | | | | | | | | | | x | | | | | | | | | | | | | | | | x | | | | | | | | x | | | | | x | | 1 | | | x | 1 | | |
| *Fursenkoina punctata* | | | | | | | | | | | | | | | | | | | | | 1 | | | | | x | | | | | | x | | | | 1 | | | | x | x | | | | x | 1 | x | | | 1 | 1 | x | 1 |
| *Glabratella lauriei* | | | | | | | 1 | 1 | 2 | x | 3 | | 1 | | | | x | | | | | | | 1 | | x | 1 | | | | | x | 2 | | | 1 | 2 | | 2 | | x | | | | | x | | | 1 | x | | | x |
| *Globobulimina auriculata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | | |
| *Guttulina caribea* | | | 1 | | | 2 | | | | | 6 | | 7 | | 1 | x | 1 | 3 | 1 | | | 1 | | | | | 2 | 1 | | | | x | | x | | | | | | x | x | | | 1 | x | x | x | | | | | x | | |
| *Guttulina lactea* | | | | | 1 | | | | | x | | | | | 1 | x | x | | x | | 1 | | | 1 | | x | | 1 | 1 | | x | 1 | | | 2 | 2 | | | | x | 2 | 1 | 1 | | | 2 | 1 | x | | | x | x | | 1 |
| *Guttulina pulchella* | | | 1 | 1 | 1 | | | 1 | | x | x | | 1 | | | x | 1 | 1 | | 2 | | 1 | | | | x | | | | | x | | | x | | | | | | x | | | 1 | | x | x | | | | | x | x | x | |
| *Gyroidina orbicularis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | | | | | | x | | | | | | | | | | | | x | |
| *Hanzawaia concentrica* | 4 | 3 | 2 | 5 | 9 | 15 | 2 | 11 | 20 | 7 | 6 | 4 | 7 | 6 | 18 | 9 | 11 | 3 | 4 | 25 | 17 | 12 | 5 | 10 | 3 | 11 | 13 | 16 | | 11 | 12 | 10 | 7 | 11 | 13 | 12 | 19 | 14 | 1 | 11 | 30 | 15 | 10 | 6 | 7 | 9 | 10 | 6 | 6 | 13 | x | 1 | 3 | 6 |
| *Haplophragmoides canariensis* | | | | | | | | | | | | | | | | x | | 2 | | | | | | | | | | | | | | | | | | | | | | x | | 1 | | 1 | x | x | | | | | x | x | | |
| *Höglindina elegans* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | | | | x | |
| *Islandiella subglobosa* | | | | | | | | | | x | x | | | | | x | | | | | | | | 1 | | x | | 1 | | 1 | 1 | 1 | 1 | | 1 | x | | | | 1 | x | | | 1 | 1 | 3 | 1 | | 1 | 9 | 5 | 15 | 7 |
| *Lagena acuticosta* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Lagena laevis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | | | | | | | | 1 | x | | x |
| *Lagena striata* | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | 1 | | x |
| *Lagena tenuis* | | | | | | | | | | | | | | | | | | | | | x | | | | | | | | | | x | x | | | | | | | | x | x | | | | | | | | | | x | x | |
| *Lenticulina orbicularis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | | | | | | | x | 1 | 4 | 1 | | x | 4 | 7 | 1 | x | x | 2 | 2 | x |
| *Marginulina advena* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | | | | | 3 | 4 | | 1 | 1 | 1 | 1 | | x | | x | x |
| *Marginulina bachei* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | | x | |
| *Marginulina villa* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | | 1 | | | |
| *Melonis pompilioides* | | | | | | | | | | | | | | | | x | | | | | | | | | | x | | | | | | | | | | | | | | x | | x | | | | | | x | x | x | 1 | x |
| *Miliolinella circularis* | | | | | | 2 | | | | | | | | | 1 | x | x | | 1 | | | | 1 | | | x | | | | | | x | | | | | | | | | | | | 1 | x | | | | | x | | | | |
| *Miliolinella fichteliana* | | | | | | | | | | | | | | | | | | | | | | | | | | x | | 1 | | | | x | | | | | | | | | x | | | | | | | | | x | | x |
| *Mississippina concentrica* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | 1 | 1 | x | x | 1 | |
| *Neoconorbina terquemi* | | | | | | | | | | 1 | | 1 | x | | | x | | x | x | | | | 2 | | 1 | 1 | 2 | | | 1 | | | x | 1 | x | | | | | 2 | 3 | 1 | | 1 | 1 | 4 | 4 | 2 | x |
| *Nodobacullariella atlantica* | | | | | | | | | | 2 | x | 2 | x | | 1 | 1 | 3 | x | 1 | | 1 | 3 | 1 | 2 | | 1 | | 3 | | | 1 | 2 | 2 | 1 | | 3 | | 2 | 1 | 1 | 4 | | 1 | 1 | 3 | 1 | | 1 | 1 | 1 | 1 | 1 | 1 |
| *Nodosaria catesbyi* | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | | | | x | | | | | | | | | | | | | x | | | | | | x | x | |
| *Nonion grateloupi* | | | | | | | | | 2 | | | | | | | x | x | | | | | | | | | | | 1 | 1 | | | | | x | | | | | | x | | | | | | x | | | | | x | 1 | |
| *Nonionella turgida* | | | | | | | | | | | | | | | | | | | | | 1 | | | | | x | | | | 1 | x | x | | | | | 1 | x | | | | | | | x | | | | | | 1 | | | x |
| *Oolina melo* | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | | | x | | | | | | | | | | | | | | | x | | | | | x | | x |
| *Patellina corrugata* | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | | | | | | | | | | | | | | | | | | | x | | | | | | | |
| *Peneroplis discoideus* | | | | | | | | | | x | | 1 | x | | | | x | | | | 1 | 1 | | 1 | | | | | 5 | | | x | | x | | x | 2 | | x | | 1 | | | | | | | | | | | | | |
| *Peneroplis proteus* | 1 | | 1 | | 4 | | 4 | 3 | | 10 | 14 | 8 | 8 | 1 | 27 | 7 | 15 | 14 | 9 | 5 | 4 | 18 | | 5 | | 3 | 3 | 13 | | 1 | 4 | 3 | 7 | 2 | 2 | 7 | 21 | 1 | | 1 | 1 | 2 | | 1 | 1 | 2 | 1 | | 1 | x | x | x | 1 |
| *Placopsilina confusa* | | | 22 | | | 4 | 39 | 1 | | 1 | | 5 | 30 | | 3 | 1 | x | 1 | 27 | | | x | 4 | | 25 | | 3 | | | 4 | | | 1 | 1 | | | | 1 | 1 | | 2 | x | 5 | | | | | 1 | | | | | |
| *Planorbulina mediterranensis* | | | | | | | | | | | | | | | | x | x | | | | | x | | | | | | | | | | x | | x | | | | | | x | | 1 | | | | | | | | x | | | |
| *Planulina ariminensis* | | | | | | | | | | | x | | | | | | x | x | | | | x | | | | | | | | | | x | | | 1 | | 1 | | x | x | | | | | | | | x | x | | 1 | 1 |
| *Planulina exorna* | 1 | | | | | | 1 | 1 | | 1 | | 1 | | 3 | | x | 1 | 1 | x | | 2 | x | 1 | 1 | | 1 | | | | | 3 | 3 | 3 | x | | x | | 1 | | 1 | 1 | 1 | | 2 | 3 | 1 | 2 | | 1 | x | 1 | 1 | 2 |
| *Planulina ornata* | 3 | 3 | | 7 | 1 | | 2 | 1 | 7 | 3 | 3 | 3 | x | | 2 | 1 | 4 | 1 | 1 | | 1 | 2 | | 2 | | 10 | | 5 | 6 | 2 | 7 | 8 | 1 | 2 | 9 | 10 | 1 | 6 | 1 | 4 | 2 | 1 | 5 | 2 | 6 | 4 | 4 | 5 | | 7 | 1 | x | 4 | 3 |
| *Pullenia quinqueloba* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | x | |
| *Pyrgo denticulata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | x | | | | 1 | | | | | | | 1 | | | x | 1 | | | 1 | x | x | x |
| *Pyrgo oblonga* | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | | | x | x | | | | | | | | | x | | | | | | x | 1 | | | x | | x | x |
| *Pyrgo serrata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | 1 | | | | | | | | | x | | x | | | | 1 | 1 | | 1 | x | x | x | |
| *Pyrgo subsphaerica* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 | | x | | | | | | | | | x | | 1 | | | | | x | 2 | | x | x | 1 | x | |

study, however, the number of specimens per cubic centimeter of wet sediment is the measure of foraminiferal abundance. Benthonic foraminifera have been shown to live within as well as on the substrate (Boltovskoy, 1966). Drying the sediment, especially if it is rich in clay and/or organic matter, may cause contraction and corresponding weight loss, which distorts the measure of abundance. Foraminiferal numbers from fine-grained sediments will be too high in comparison with those from clean, coarse-grained sediments. Walton (1955) discusses this problem in detail.

The populations of planktonic and benthonic foraminifera are treated separately, so that the total count for each group is considered 100%.

The following discussions pertain to total foraminiferal populations, which, because of the scarcity of living specimens are in effect thanatocoenoses. Analysis of the biocoenoses would have been qualitative at best.

### A. Benthonic Foraminifera

The two faunal realms on the North Carolina continental shelf are separated by a major faunal boundary near Cape Hatteras as has already been demonstrated (Bumpus and Pierce, 1955). The distinction is especially marked for mollusks (Abbott, 1954). These northern and southern faunas have been termed Virginian and Carolinian respectively by Johnson (1934). This boundary, however, appears gradational when foraminifera only are considered. Foraminiferal faunas north of Cape Hatteras are similar to those described by Parker (1948) from the coast of Maryland to Cape Cod, and to a lesser degree to those of New Hampshire (Phleger, 1952; Parker, 1952). Foraminiferal faunas south of Cape Lookout closely resemble those listed by Wilcoxon (1964) from the continental shelf of the Southeastern United States, and, to some extent, with faunas of the northeastern Gulf of Mexico (Parker, 1954). The shelf between Cape

TABLE Ib (continued)

| STATION NUMBER | 2145 | 2146 | 2142 | 2307 | 2141 | 2277 | 2139 | 2151 | 2287 | 2137 | 2138 | 2110 | 2127 | 1734 | 1965 | 2116 | 2118 | 2122 | 2123 | 3348 | 1977 | 2117 | 2156 | 2111 | 3269 | 1960 | 2296 | 1963 | 3346 | 3347 | 1737 | 1738 | 1739 | 2109 | 1741 | 2166 | 1975 | 2159 | 3342 | 2108 | 1979 | 2107 | 3340 | 2105 | 2168 | 1750 | 1980 | 3339 | 2171 | 1759 | 2172 | 2104 | 2175 | 1783 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DEPTH IN METERS | 12 | 12 | 15 | 16 | 17 | 18 | 20 | 20 | 20 | 22 | 22 | 23 | 23 | 24 | 25 | 25 | 25 | 25 | 25 | 25 | 26 | 26 | 26 | 28 | 28 | 29 | 29 | 30 | 30 | 30 | 33 | 33 | 33 | 36 | 41 | 42 | 44 | 50 | 50 | 52 | 55 | 57 | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 122 | 125 | 140 | 155 | 159 |
| *Quinqueloculina bicostata* | | | 3 | | 4 | 2 | 1 | | | 2 | 3 | 2 | 2 | 3 | 1 | 1 | 2 | 5 | 2 | 2 | | 1 | | 5 | | | 5 | 1 | | 1 | 1 | x | 2 | 2 | | 1 | | | | x | x | | | | | x | | | 1 | 1 | 1 | | 1 |
| *Quinqueloculina bosciana* | | • | | | | | | | | 1 | | | | | | x | 1 | x | 1 | | | | | 1 | | 1 | | 1 | | | | x | | x | | | | | | | 1 | | | | | | 1 | 1 | | x | x | 1 | x | |
| *Quinqueloculina compta* | 1 | 1 | 4 | 2 | 10 | | 2 | 6 | | 5 | 7 | 1 | x | 4 | 1 | 2 | 2 | 2 | 1 | 5 | 7 | 2 | 8 | 5 | 2 | 5 | 2 | 2 | | 3 | 9 | 6 | 4 | 2 | 1 | | 4 | 3 | | 2 | 1 | 1 | 1 | 1 | | 1 | x | x | | x | x | x | x | x |
| *Quinqueloculina jugosa* | 4 | 3 | 2 | | 2 | 2 | 1 | 7 | 2 | 1 | 1 | 4 | | 8 | | 1 | 2 | 1 | 1 | 2 | 3 | 3 | 3 | 1 | 2 | 2 | 1 | 1 | | | 1 | 2 | 1 | 5 | | 1 | 2 | 3 | | 1 | 1 | 5 | x | 1 | 1 | 1 | x | | | 4 | x | 1 | x | 1 |
| *Quinqueloculina lamarckiana* | | 6 | 6 | 4 | 8 | | 6 | 11 | | 8 | 5 | | 2 | 2 | | 2 | 4 | 6 | 5 | | 1 | 4 | | 3 | | 3 | 1 | 3 | | | 1 | 2 | 1 | 3 | | 2 | 1 | 4 | | 4 | 1 | 2 | 1 | 1 | 2 | 3 | 1 | 1 | 2 | 1 | | x | | x |
| *Quinqueloculina poeyana* | | | | 2 | | | | | | x | | | | 1 | | | | | | | | x | | 1 | | 2 | | | | | 1 | 2 | 1 | | | | | | | 1 | 1 | | | | 1 | x | x | | x | 1 | 1 | 1 | 1 |
| *Quinqueloculina seminula* | 7 | 5 | 18 | 6 | 27 | 31 | 9 | 11 | 9 | 5 | 12 | 30 | 2 | 46 | 10 | 8 | 6 | 23 | 6 | 11 | 9 | 9 | 18 | 14 | 11 | 8 | 7 | 4 | | 19 | 9 | 4 | 28 | 14 | 3 | 5 | 9 | 15 | | 5 | 13 | 12 | 4 | 19 | 6 | 4 | 5 | 14 | 28 | 19 | 1 | 9 | 5 | 4 |
| *Rectobolivina advena* | | | | | | | | | | | | | x | | | | x | | | | | | | | | x | | | | | x | | x | | | | | | | | | | | | | | | | | x | 1 | x | |
| *Reophax atlantica* | | | 2 | 1 | | | 4 | 13 | 11 | 2 | 3 | | 2 | | 1 | 2 | 1 | | 3 | 7 | 1 | | 5 | 2 | | | 9 | | 1 | 2 | 1 | x | 2 | x | | x | 1 | 3 | 1 | x | x | 1 | 2 | 2 | x | | x | 4 | 1 | | 1 | | 1 | |
| *Reophax fusiformis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 | | | |
| *Reophax scorpiurus* | | | 1 | | 3 | | 1 | 3 | | 3 | 2 | 2 | 3 | 1 | 4 | 2 | 2 | 14 | 7 | 16 | 8 | 1 | 1 | 2 | 2 | 1 | 10 | 8 | | 10 | 3 | 2 | 7 | 2 | 3 | 1 | 1 | 3 | 1 | 4 | 1 | 4 | 4 | 3 | 2 | 1 | 2 | 2 | 2 | x | | x | x | x |
| *Reussella atlantica* | 3 | 1 | | | | | | | 1 | 1 | | 1 | | | x | 1 | | x | | | | | | | 2 | | 1 | | | 4 | 2 | 2 | | 3 | 1 | | | | 1 | | | | 1 | x | | x | | x | x | x | x | 1 | 1 |
| *Robertinoides normani* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | |
| *Rosalina floridana* | 1 | | | 1 | 2 | | | 1 | | 1 | x | | 1 | 1 | | 1 | x | x | | | 1 | 1 | | | | 2 | 2 | 1 | | | 2 | 1 | 1 | x | | 1 | 1 | | | x | | | | 2 | | x | | 1 | 2 | 1 | 2 | x |
| *Rosalina floridensis* | | | | | | 2 | | | | | | | | | | | | | | | | x | | | | | | | | | | x | | | | | | | | x | x | | | | | | x | | | 1 | 1 | x | |
| *Rosalina globularis* | 2 | | 2 | 1 | 1 | 6 | 1 | 6 | 2 | 2 | | | 1 | | | 3 | 2 | 1 | 1 | | 2 | 1 | 8 | 2 | | 3 | 2 | 3 | | | 1 | 2 | 1 | x | 1 | | 2 | 1 | 1 | 3 | 3 | | 1 | | 5 | 2 | 3 | 1 | | x | 10 | 7 | 3 | 1 |
| *Rosalina rugosa* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Sagrina pulchella* | | | | | | | | | | 1 | | | x | | | 1 | | | | | | | | 1 | | x | | | | | x | 1 | 1 | | | | | | | | x | x | | | | x | 1 | | | | x | x | x | | x |
| *Scuituloris procera* | 1 | | 1 | | | 4 | 1 | | | 1 | | | | | | 3 | 2 | 1 | 1 | | 3 | 2 | 3 | 1 | | 1 | | 1 | | | 1 | 3 | 1 | x | | | | | | 1 | x | | | | 3 | 4 | 2 | | | 1 | 5 | 6 | 4 | 2 |
| *Sigmoilina antillarum* | | | | | | | | | | | | | x | | | x | x | x | x | | | | | | | 1 | | | | | | 1 | | x | | | | | | x | x | | | | x | x | | | | | x | | x | x |
| *Sigmoilina tenuis* | | | | | | | | | | | | | | | | | x | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x | |
| *Siphonaptera horrida* | | | | | | | | | | x | 1 | 1 | | | | 1 | 1 | 1 | | | | 1 | | | | x | 1 | 3 | | | | | | | 1 | | 4 | | | 1 | | 1 | | | | 1 | 8 | | | | | | x | |
| *Siphonaptera sabulosa* | 2 | | 8 | | 6 | | 1 | | 4 | 1 | 2 | 1 | | | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 1 | | 1 | | 1 | 3 | | | 1 | 3 | 2 | 2 | 1 | 1 | 1 | 1 | | | 1 | x | 1 | x | 1 | x | 1 | x | | | 1 | | | x | 1 |
| *Siphonina pulchra* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | x |
| *Siphotextularia curta* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | | |
| *Siphotextularia rolshauseni* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | | |
| *Sphaeroidina bulloides* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | | x |
| *Spiroloculina atlantica* | | | | | | | 1 | | | x | | | x | | | | | x | | | 1 | | | 1 | | | | | | x | 1 | 1 | 1 | | x | 2 | | | x | x | | | | 1 | | x | x | | | x | | | x | x |
| *Spiroloculina depressa* | | | | | | | | | | | | | | | | x | | | | | | | | | | | | | | | x | | | | | | | | | x | | | | | | | | | | x | | | |
| *Spiroplectammina floridana* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | x |
| *Stainforthia complanata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | | | | | | | | | | | | | | | | | | x | | | |
| *Stetsoina minuta* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x | 1 |
| *Stilostomella antillea* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | |
| *Textularia candeiana* | 3 | | 7 | 1 | 7 | | | | | 1 | 1 | 2 | | 2 | | 1 | 1 | 2 | x | 2 | 2 | 1 | 1 | 4 | 3 | | | 1 | | 2 | 3 | x | 1 | 2 | 1 | x | | 2 | | 2 | 2 | 3 | 1 | 1 | 3 | 3 | x | 2 | 5 | 2 | 1 | 1 | 2 | 1 |
| *Textularia conica* | 5 | | 2 | 4 | 1 | 2 | 1 | 3 | | 5 | 2 | 2 | 2 | 3 | | 3 | 3 | 1 | 2 | | 2 | 4 | 8 | 2 | 6 | 1 | 2 | 3 | | | 2 | 2 | 1 | 4 | 2 | 2 | 1 | 2 | | 4 | 2 | 4 | 1 | 2 | 4 | 5 | 1 | 2 | 3 | 1 | 3 | 3 | 2 | 2 |
| *Textularia pseudotrochus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | 1 | | | | | | | | | | | | | | 1 | 1 | 3 | | | 1 | | |
| *Textularia truncata* | 6 | 1 | 1 | 2 | 1 | 2 | | 3 | | 2 | 1 | | 2 | 1 | 1 | 2 | 3 | 3 | 2 | 3 | 2 | 2 | 3 | | | x | 2 | | | 3 | x | x | 1 | 1 | | x | | 1 | | 1 | 3 | 3 | 1 | 1 | 3 | 1 | x | 3 | 2 | 1 | x | 2 | x | 1 |
| *Textulariella barrettii* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | 3 | | | 1 | 3 | | | x | x |
| *Trifarina angulosa* | | | | 1 | | | | | | 1 | x | | | 1 | | 2 | x | x | 1 | | 2 | | 2 | 2 | | 2 | 1 | 1 | | | x | 1 | | x | 1 | x | | 1 | 1 | 1 | 1 | 1 | | | 2 | 2 | 1 | x | | x | 4 | 7 | 4 | 4 |
| *Trifarina bradyi* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x |
| *Triloculina tricarinata* | | | | | | | | | 2 | | | | | | | | | | | | | | | | | | | | | | | x | | | | | | | | | | | | | | | | | | x | | | |
| *Triloculina trigonula* | | | 1 | 1 | | 2 | 1 | | 4 | | | | | 5 | | | 1 | x | | | | | 2 | | | 1 | | 1 | 1 | | 3 | 3 | 1 | 1 | | 2 | | 1 | | x | 3 | 1 | 2 | | 1 | 2 | 3 | 2 | | | x | 1 | x | |
| *Trochammina advena* | | x | | | | | | | | | | | | | x | x | | | | | | | | | | x | | | | | | | | | | | | | | | | | | | | | | x | | | x | x | x | |
| *Trochammina squamata* | | | 3 | | | | 1 | | 4 | x | | | 1 | | | 1 | | | | | | | | | | | 1 | | | | | | | | x | | | | | | | | | | | | | | | | | 1 | 1 | 1 | x | |
| *Trochamminula lobata* | | | 2 | 1 | | 2 | | 1 | 4 | x | x | | | | 1 | x | | | 1 | | | | 2 | 1 | | x | | | 1 | 1 | | | | | | | | | | | | | | | | | | | | | 1 | 1 | x | |
| *Uvigerina auberiana* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | x | 1 |
| *Uvigerina peregrina* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | x | 1 |
| *Valvulineria laevigata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | |
| *Webbinella concava* | 1 | | | | 2 | 6 | 1 | | 2 | x | | | 1 | 1 | 2 | x | x | x | 1 | 2 | | x | | | 2 | | 2 | 1 | | 3 | x | | 2 | x | | | 2 | | | x | 1 | | | | x | | 1 | 2 | 1 | x | | | |
| *Wiesnerella auriculata* | | | | | | | | | | x | | | x | | | | x | | | | | | | | | x | | | | | | x | | | 1 | | | | | | x | | | | | | | | | x | x | 1 | x | x |

Lookout and Cape Hatteras, however, supports a fauna of mixed character, though southern elements generally dominate. Many species range through the study area and show no marked preference for either realm.

## B. Areal and Depth Distribution of Benthonic Foraminifera

Tables I and II present the abundance and distribution of each benthonic species in the samples which are arranged according to depth of occurrence. Table I presents the total benthonic fauna, but table II includes only the living individuals. For the most significant species, distribution maps have been plotted. Species occurrences are conventionally grouped into characteristic thanatotopes, defined by maximum abundance or the upper and lower limits of occurrence of one (= auto-thanatotope) or several (= syn-thanatotope) key species. The following thanatotopes are herein defined for the North Carolina continental shelf:

I a. Near shore—north of Cape Hatteras. This area is essentially an auto-thanatotope, defined by *Elphidium clavatum* abundances of greater than 50% of the total benthonic fauna (figure 3). The landward limit of this area is very poorly defined because few near shore samples were taken.

II. Central shelf—The shelf between about 20 meters and 60 meters depth is here regarded as central shelf from the viewpoint of faunal distribution. It is subdivided into the following syn-thanatotopes:

a. Central shelf, north of Cape Hatteras. The diagnostic species for this syn-thanatotope are *Elphidium clavatum* with frequencies between 50% and 15%, *Hanzawaia concentrica* (fig. 4) with more than 10% and *Reophax atlantica* (fig. 5) with more than 10% of the total benthonic population. *R. atlantica,* however, shows its greatest abundance near the southern portion of the northern area. *Webbinella concava* and *Guttulina lactea* may also be considered diagnostic for

TABLE II a DISTRIBUTION OF LIVING FORAMINIFERA (North of Cape Hatteras)

| STATION NUMBER | 1938 | 2267 | 1992 | 3333 | 3336 | 3337 | 2001 | 2007 | 3332 | 2006 | 1985 | 1997 | 2009 | 2264 | 1994 | 2260 | 2265 | 2010 | 2011 | 2258 | 2256 | 3325 | 3338 | 2254 | 2017 | 2251 | 3324 | 2243 | 2025 | 2247 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DEPTH IN METERS | 19 | 19 | 20 | 20 | 20 | 20 | 22 | 22 | 22 | 23 | 25 | 25 | 26 | 26 | 28 | 32 | 35 | 38 | 38 | 38 | 50 | 50 | 60 | 70 | 80 | 90 | 95 | 110 | 120 | 140 |
| *Ammobaculites dilatatus* | | | | | | | | | | | | | | | | | | | | | | | | | | 2 | | | | |
| *Ammodiscus catinus* | | | | | | | | | | | | | | | | | | | 1 | | 2 | | | 1 | | | | | | |
| *Ammonia beccarii* | | | | | | | 2 | | | | | | | | 1 | | | | | | | | | | | | | | | |
| *Asterigerina carinata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Asterigerinata pulchella* | | | | | | | 2 | 3 | | 1 | | 1 | 10 | | | | 2 | 3 | 1 | 1 | 1 | | | | | | | | | |
| *Bolivina lowmani* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Bolivina pseudoplicata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Bolivina subaen. mexicana* | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | 2 |
| *Buccella hannai* | | | | | | | | | | | | | 4 | | | | | | | | | | | | | | | | | |
| *Bulimina aculeata* | | | | | | | 2 | | | | | | | 1 | | | | | 1 | | | | | 1 | 1 | | | | | |
| *Bulimina marginata* | | | | | | | | | | | | | | | | | | 1 | | 1 | | | | 3 | | 4 | 1 | 3 | | |
| *Calcituba decorata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Cancris sagra* | | | | | | | | | | | | | | | | | 1 | 6 | | 1 | 2 | 2 | | 4 | 1 | 4 | 1 | 2 | | 3 |
| *Caribeanella polystoma* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Cassidulina neocarinata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Cassidulinoides bradui* | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | 1 | 3 |
| *Cibicides bradyi* | | | | | | | | | | | | | | | | | | | 1 | | | | | 1 | | | | 1 | | |
| *Cibicides pseudoungerianus* | | | | | | | | | | | | | | | | | | | | | | | | 2 | 1 | 2 | | | 1 | |
| *Cymbaloporetta atlantica* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Dentalina communis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Discorbinella bertheloti* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Eggerella advena* | | | | | | | 5 | | | 1 | 3 | 2 | 1 | | 4 | 1 | | 2 | 1 | 2 | 5 | | | | | | | | | |
| *Elphidiella mexicana* | | | | | | | | | | | | | | 1 | | 1 | | | 1 | 3 | 2 | | | | | 1 | | | | |
| *Elphidium clavatum* | 1 | 1 | 4 | | | | 9 | | | | 2 | 1 | | 1 | 2 | | | 6 | 5 | 5 | 3 | | | | | | | | | |
| *Elphidium incertum* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Elphidium subarcticum* | | | | | | | | | | | | | | | | | | | 1 | | 3 | | | | | | | | | |
| *Eponides antillarum* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Eponides repandus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Fissurina lucida* | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | |
| *Fissurina stewartii* | | · | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | |
| *Florilus atlanticus* | | | | | | | 1 | | | 1 | 1 | | | | | | | 2 | 1 | 1 | | | | | | 3 | | | | |
| *Florilus auriculus* | | | | | | | | | | | | | | | | | | | | | | | | | | 2 | | | 1 | |
| *Fursenkoina fusiformis* | | | | | | | | | | | | | | | 2 | | 1 | 1 | | | 20 | | | | | 2 | | | | |
| *Fursenkoina punctata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Guttulina caribea* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Guttulina lactea* | | | | | | | 2 | | | 1 | | 1 | 11 | | | 1 | | 6 | 2 | | | | | | | | | | | |
| *Guttulina pulchella* | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | |
| *Hanzawaia concentrica* | 1 | | | | 1 | | 13 | | | 1 | 2 | | | 1 | 1 | 1 | 1 | 22 | | 1 | 1 | 1 | | | | | | | | |
| *Haplophragmoides canariensis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Höglundina elegans* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

this syn-thanatotope; they attain frequencies of more than 5% in the most northern transect, but their abundance diminishes towards the south.

b. Central shelf, Raleigh Bay. Characteristic for this syn-thanatotope are *Hanzawaia concentrica* with more than 10%, *Reophax atlantica* with more than 10% and *Peneroplis proteus* (fig. 6) with more than 10% of the total benthonic population. Of these, *R. atlantica* is more abundant in the shallower portion of this area. *Quinqueloculina seminula* (10%), *Asterigerina carinata* (fig. 7) (12%), and *Reophax scorpiurus* (5%) have patchy distributions, but where they attain frequencies higher than those indicated, they are also diagnostic and may serve to identify this thanatotope. *Quinqueloculina compta* (fig. 9) is relatively rare, but frequencies of more than 4% are characteristic for this area.

c. Central shelf, south of Cape Lookout. *Peneroplis proteus* with more than 14% and *Placopsilina confusa* (fig. 8) with more than 20%, most persistently characterize this syn-thanatotope, together with the more rare *Quinqueloculina compta* (5%). The following species have patchy distribution, but signify the central shelf where the indicated frequencies are reached: *Quinqueloculina seminula* (20%), and *Reophax scorpiurus* (5%). *Asterigerina carinata* with more than 6%, and *Quinqueloculina lamarckiana* with more than 5% are more typical of the southern portion of this syn-thanatotope.

III. Shelf edge—Upper Continental Slope. The depth limits for this area are approximately 60 meters and 140 meters. Even though the depth range is twice that of the central shelf, the geographic area is considerably smaller because of the greatly in-

TABLE IIa (continued)

| STATION NUMBER | 1938 | 2267 | 1992 | 3333 | 3336 | 3337 | 2001 | 2007 | 3332 | 2006 | 1985 | 1997 | 2009 | 2264 | 1994 | 2260 | 2262 | 2010 | 2011 | 2258 | 2256 | 3325 | 3338 | 2254 | 2017 | 2251 | 3324 | 2243 | 2025 | 2247 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DEPTH IN METERS | 19 | 19 | 20 | 20 | 20 | 20 | 22 | 22 | 22 | 23 | 25 | 25 | 26 | 26 | 28 | 32 | 35 | 38 | 38 | 38 | 50 | 50 | 60 | 70 | 80 | 90 | 95 | 110 | 120 | 140 |
| *Islandiella subglobosa* | | | | | | | | | | | | | | | | | | 1 | | | 1 | | | | 1 | 1 | 2 | | | |
| *Lagena striata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Lenticulina orbicularis* | | | | | | | | | | | | | | | | | | | | | | | | 3 | 1 | 4 | | 1 | | 1 |
| *Miliolinella circularis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Mississippina concentrica* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Neoconorbina terquemi* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Nodobacullariella atlantica* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Nonion grateloupi* | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | |
| *Peneroplis proteus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Placopsilina confusa* | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | |
| *Planorbulina mediterranensis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Planulina exorna* | | | | | | | | | | | | | | | | | | 2 | | | 1 | | | | | | 1 | | | 1 |
| *Planulina ornata* | | | | | | | | | | | | | | | | | | | | 1 | 1 | | | 2 | 1 | | | | | |
| *Pyrgo denticulata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Pyrgo oblonga* | | | | | | | | | | | | | | | | | | | | 1 | | | | | | 3 | | | | 1 |
| *Pyrgo serrata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Quinqueloculina bicostata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Quinqueloculina bosciana* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Quinqueloculina compta* | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | |
| *Quinqueloculina jugosa* | | | | | | | | | | | 1 | | | | | | | 1 | 1 | | | | | | | | | | | |
| *Quinqueloculina lamarckiana* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Quinqueloculina poeyana* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Quinqueloculina seminula* | | | | | | | | | | | | | 1 | | | 2 | 1 | 12 | 2 | 6 | 1 | | | | | | | | | |
| *Rectobolivina advena* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Reophax atlantica* | | 3 | 5 | | | | | | 4 | | 1 | 2 | | 11 | 7 | 2 | 3 | 3 | | 13 | 6 | | | 11 | 1 | 12 | 1 | 1 | | 3 |
| *Reophax fusiformis* | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | |
| *Reophax scorpiurus* | 1 | | | | | | 2 | | | | 2 | | | | | | 1 | | | | | | | 3 | | 1 | | | | |
| *Reussella atlantica* | | | | | | | | | | | | | | | | 5 | | | | | | | | | | | | | | |
| *Rosalina floridana* | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | |
| *Rosalina floridensis* | | | | | | | | | | | | | | | | | | | 2 | | | | | | | | | | | |
| *Rosalina globularis* | | | | | 1 | | | | | | | | | | | 1 | | | | | | | | 1 | 1 | 1 | | | | |
| *Rosalina rugosa* | | | | | | | | | | | | | | | | | | | | | 3 | | | | | 3 | | | | 1 |
| *Sagrina pulchella* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Scuturoris procera* | | | | | | | 1 | | | | | | | | | 1 | | | 1 | 3 | | | | | | | | | | |
| *Spiroloculina atlantica* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Stetsoina minuta* | | | | | | | | | | | | | | | | | | | | | 1 | | | | | 2 | | | | |
| *Textularia candeiana* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Textularia conica* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Textularia truncata* | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | |
| *Trifarina angulosa* | | | | | | | | | | | | | | | | | | | | | | | | | | 2 | | | | 1 |
| *Triloculina trigonula* | | | | | | | | | | | | | | | | | | 1 | 1 | | | | | | | | | | | |
| *Trochammina squamata* | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | 1 |
| *Trochamminula lobata* | | | | | | | | | | | | | 7 | | 1 | | | | | 1 | 2 | | | | | 3 | | 1 | | 2 |
| *Webbinella concava* | | | | | | | 4 | 1 | | 4 | | | 1 | 1 | 2 | | 1 | 1 | | 1 | | 1 | | | | | | | | |
| *Wiesnerella auriculata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

creased bottom gradient. Species distribution is more uniform than on the central shelf, but three subdivisions also are recognized.

a. Shelf-edge, north of Cape Hatteras. In this syn-thanatotope *Islandiella subglobosa* (fig. 11) and *Bulimina marginata* (fig. 12) are present with frequencies of more than 10%, *Lenticulina orbicularis* (fig. 13), and *Cibicides pseudoungerianus* with more than 5% and *Trifarina angulosa* with more than 2%. *Eponides punctulatus* occurs with frequencies of about 4%, but is irregularly distributed. *Cibicides bradyi* is characteristic for this syn-thanatotope with frequencies of more than 5%, but south of Cape Hatteras it is no longer diagnostic for this depth as it occurs abundantly in shallow water also.

b. Shelf edge, Raleigh Bay. This thanatotope is not defined precisely because of the availability of only a few samples, of which none were obtained at depths greater than 90 meters. *Lenticulina orbicularis* occurs with frequencies of more than 4%, the abundance of *Amphistegina lessonii* (fig. 14) ranges from 1 to 8%. *Cibicides pseudoungerianus* with frequencies of more than 6% is restricted to this area, but expands its distribution into shallower water south of this area.

c. Shelf edge, south of Cape Lookout. *Islandiella subglobosa* characterizes this area with frequencies of more than 5%, with *Lenticulina orbicularis* reaching more than 2% and *Trifarina angulosa* more than 4%. The abundance of *Amphistegina lessonii* varies between 1 and 16%.

The lower distribution limits of many of these species are undetermined as no sample from a depth of more than 159 meters was taken. The frequency diagrams (figures 20 to 29) indicate, however, that their abundances decline below about 120 meters. Table IV summarizes the composition of the different thanatotopes.

## C. Species Dominance

The distribution of the dominant species is represented in Figure 15. The distribution pattern is very simple to the north and just south of Cape Hatteras. Here the entire shelf is characterized by *Elphidium clavatum,* which gives way at the shelf edge to *Islandiella subglobosa.* South of Cape Hatteras the distribution pattern becomes more complex. *Elphidium clavatum* dominates two patches, one just west of Cape Lookout, in the vicinity of Beaufort Inlet, and one south-

TABLE II b DISTRIBUTION OF LIVING FORAMINIFERA ( South of Cape Hatteras)

| STATION NUMBER | 2145 | 2146 | 2142 | 2307 | 2141 | 2277 | 2139 | 2151 | 2287 | 2137 | 2138 | 2110 | 2127 | 1734 | 1965 | 2116 | 2118 | 2122 | 2123 | 3348 | 1977 | 2117 | 2156 | 2111 | 3269 | 1960 | 2296 | 1963 | 3346 | 3347 | 1737 | 1738 | 1739 | 2109 | 1741 | 2166 | 1975 | 2159 | 3342 | 2108 | 1979 | 2107 | 3340 | 2105 | 2168 | 1750 | 1980 | 3339 | 2171 | 1759 | 2172 | 2104 | 2175 | 1783 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DEPTH IN METERS | 12 | 12 | 15 | 16 | 17 | 18 | 20 | 20 | 20 | 22 | 22 | 23 | 23 | 24 | 25 | 25 | 25 | 25 | 25 | 25 | 26 | 26 | 26 | 28 | 28 | 29 | 29 | 30 | 30 | 30 | 33 | 33 | 33 | 36 | 41 | 42 | 44 | 50 | 50 | 52 | 55 | 57 | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 122 | 125 | 140 | 155 | 159 |
| *Ammobaculites dilatatus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | – | | |
| *Ammodiscus catinus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | – | | |
| *Ammonia beccarii* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Asterigerina carinata* | | | | | | | | | | 3 | | | 5 | | | 12 | 5 | 1 | | | | 1 | | | | | 1 | | | | | | | | | | | 1 | | | 1 | | | | | | | | | | | | | | |
| *Asterigerinata pulchella* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Bolivina lowmani* | | | | | | | | | | | | | | | | 3 | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Bolivina pseudoplicata* | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Bolivina subaen. mexicana* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 | 2 | | |
| *Buccella hannai* | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| *Bulimina aculeata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Bulimina marginata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| *Calcituba decorata* | | | | | | 1 | | | | | | 2 | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Cancris sagra* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 | | | | | | 3 | | | 1 | 4 | 2 | | | |
| *Caribeanella polystoma* | | 1 | | | | 6 | | | 3 | | | 6 | | | | | 2 | 2 | 5 | | | | 8 | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Cassidulina neocarinata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | 3 | | 7 | |
| *Cassidulinoides bradyi* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Cibicides bradyi* | | | | | | | | | | | | 2 | | | | 8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | 1 | |
| *Cibicides pseudoungerianus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | 1 | | 2 | |
| *Cymbaloporetta atlantica* | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Dentalina communis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Discorbinella bertheloti* | | | | | | | | | | | | | | | | | | | 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Eggerella advena* | | | | | | | | | | | | | | | | 6 | | | | | | | | | | | | | | | | 1 | | | | | | | | | | 1 | | | | | | | | | | | | 1 |
| *Elphidiella mexicana* | | 1 | | | | | 1 | | | | 2 | | | | | | 1 | | | | | | | | | | 1 | | | | | | | | | | | | | | 5 | | | | | | | | | | | | |
| *Elphidium clavatum* | | 1 | | | | | 1 | 1 | | | | | | 1 | | 2 | | | | | | | | | | | | | | | | | 1 | 1 | 2 | | | 1 | | | | | | | | | | | | | | |
| *Elphidium incertum* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | |
| *Elphidium subarcticum* | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | |
| *Eponides antillarum* | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | 3 | | 1 | | | 1 | | | | | | | | |
| *Eponides repandus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | |
| *Fissurina lucida* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Fissurina stewartii* | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Florilus atlanticus* | | | | | | | | | 1 | | | | | | | 7 | 1 | | | | | | | | | | | | | | 1 | | 1 | | | | | | 6 | 1 | | | | | | | | | | | | |
| *Florilus auriculus* | | | | | | | | | | | | | | | 1 | | | | | | 1 | | | | | | | | | | 1 | | | | | | | | 1 | | | | | | | | | | | | | |
| *Fursenkoina fusiformis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | |
| *Fursenkoina punctata* | | 1 | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Guttulina caribea* | | 1 | | | 2 | | | | | | 1 | | 4 | | | | | 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Guttulina lactea* | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | 1 | | | | | | | | 1 | | | | | | | | | | | | |
| *Guttulina pulchella* | | | | | | | | | | | | | 1 | | | | | | | | 1 | | | | | | | | | | | | | | | | | 2 | | | | | | | | | | | | | | | |
| *Hanzawaia concentrica* | | 1 | | | 1 | | 5 | 4 | 1 | 1 | | 4 | | 2 | 8 | 5 | 3 | 1 | 3 | 1 | 2 | 3 | 3 | | 5 | 1 | 2 | | 3 | 5 | 1 | 1 | 3 | 1 | 2 | 3 | | 2 | 6 | 6 | | | 1 | 4 | | | 2 | | | | |
| *Haplophragmoides canariensis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | 1 | | | | |
| *Höglundina elegans* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | |

east of Cape Lookout, on the outer portion of the central shelf and along the shelf edge. *Hanzawaia concentrica* dominates large portions of the central shelf between Cape Hatteras and Cape Lookout (Raleigh Bay). The central portion of the shelf of Raleigh Bay is occupied by *Peneroplis proteus,* which occurs again south of Cape Lookout, but there it is restricted to depths of less than 30 meters. *Quinqueloculina seminula* has a patchy distribution. It occurs just south of Cape Hatteras in very shallow water (18 meters) and is present also southeast of Cape Hatteras on the outer part of the central shelf and shelf edge. Its greatest areal distribution was noted southeast of Cape Lookout in samples from less than 40 meters depth. As along the shelf edge off Cape Hatteras, this species also is dominant in a few shelf edge samples off Cape Lookout where it is bordered on the seaward side by *Islandiella subglobosa. Placopsilina confusa* dominates in a number of samples south of Cape Lookout, but only at depths of less than 30 meters.

It is apparent, that in many cases the dominant species in any particular area is also a member of the diagnostic species group for that area. The notable exception to this generalization is the dominance of *Elphidium clavatum* over the entire northern shelf and over certain portions of the southern area. It is obvious, then, that in certain cases, recognition of a particular environment is based on minor faunal elements, preferably on assemblages whose composition may differ within limits.

## D. Total Benthonic Foraminifera

The absolute abundance of benthonic specimens generally increases with depth (or distance from shore) (Fig. 16). This increase is very regular north of the latitude of Cape Lookout. In this area less than 100 specimens per sample are found above depths of 30 to 40 meters. Below this depth the number of specimens per sample increases abruptly to a maximum of 1990 specimens per cubic centimeter at 140 meters

TABLE II b (continued)

| STATION NUMBER | 2145 | 2146 | 2142 | 2307 | 2141 | 2277 | 2139 | 2151 | 2287 | 2137 | 2138 | 2110 | 2127 | 1734 | 1965 | 2116 | 2119 | 2122 | 2123 | 3348 | 1977 | 2117 | 2156 | 2111 | 3269 | 1960 | 2296 | 1963 | 3346 | 3347 | 1737 | 1738 | 1739 | 2109 | 1741 | 2166 | 1975 | 2159 | 3342 | 2108 | 1979 | 2107 | 3340 | 2105 | 2168 | 1750 | 1980 | 3339 | 2171 | 1759 | 2172 | 2104 | 2175 | 1783 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DEPTH IN METERS | 12 | 12 | 15 | 16 | 17 | 18 | 20 | 20 | 20 | 22 | 22 | 23 | 23 | 24 | 25 | 25 | 25 | 25 | 25 | 25 | 26 | 26 | 26 | 28 | 28 | 29 | 29 | 30 | 30 | 30 | 33 | 33 | 33 | 36 | 41 | 42 | 44 | 50 | 50 | 52 | 55 | 57 | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 122 | 125 | 140 | 155 | 159 |
| *Islandiella subglobosa* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | 1 | | 2 | |
| *Lagena striata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | |
| *Lenticulina orbicularis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | 1 | |
| *Miliolinella circularis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Mississippina concentrica* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | |
| *Neoconorbina terquemi* | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Nodobacullariella atlantica* | | | | | | | | | | | | | | | | 1 | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Nonion grateloupi* | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Nonionella turgida* | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | |
| *Peneroplis proteus* | | | | | | | | | | | | | | | | | 1 | | | | | 3 | | | | | | | | | | | | | | | | 2 | | 3 | | | | | | | | | | | | | | | | |
| *Placopsilina confusa* | | | 2 | | | | | | | | | | | | 1 | | | | | | | | 1 | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | |
| *Planorbulina mediterranensis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | |
| *Planulina exorna* | | | | | | | | | | | | | | 1 | | | | | | | | | | | | 1 | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | |
| *Planulina ornata* | | | | | | | | | | 1 | | | | | 1 | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Pyrgo denticulata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | |
| *Pyrgo oblonga* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Pyrgo serrata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | 1 | | | | | | | | 1 |
| *Quinqueloculina bicostata* | | | | | | | | | | | | | | | | | 1 | 1 | | | | | | 2 | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Quinqueloculina bosciana* | | | | | | | | | | | | | | | 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 | | | | | | | | |
| *Quinqueloculina compta* | 1 | | 1 | | | | | | 2 | | | | 3 | | 2 | 1 | | | | | 1 | 2 | | 4 | | | | | | | 6 | 1 | 1 | 2 | | 1 | | 1 | | 1 | | 1 | | | | | | | | | | | 1 | |
| *Quinqueloculina jugosa* | | | | | | | | 1 | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | |
| *Quinqueloculina lamarckiana* | | | | | | | 5 | | | | | | | | | | | | | | | 2 | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Quinqueloculina poeyana* | | | 1 | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Quinqueloculina seminula* | | 1 | 1 | | | | | 1 | | 2 | 1 | | | | | 1 | 1 | 1 | | | | | 1 | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | 6 | 1 | |
| *Rectobolivina advena* | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | |
| *Reophax atlantica* | | | 1 | 1 | | | 2 | 3 | 2 | | 4 | | | | | 2 | 1 | | | | 1 | 1 | | 1 | | | 2 | | | | 2 | | | | | | | 1 | 1 | | | | 2 | 1 | | | | 1 | | 1 | | | | |
| *Reophax fusiformis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Reophax scorpiurus* | | | | | | | | 2 | | 1 | | | | | 1 | | 2 | 1 | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | 1 | | | | | | |
| *Reussella atlantica* | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 | 1 | | | 1 | | | | | | | | | | | | | | | | | 2 | | |
| *Rosalina floridana* | | | | | | | | 1 | | 2 | | | 2 | 1 | | | | | | | | 1 | | | | | 1 | 1 | | | | 1 | | | | | | 1 | | | | | | | | | | | | | | | | 1 | | |
| *Rosalina floridensis* | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | 1 | | |
| *Rosalina globularis* | | | 2 | | 2 | | 3 | 2 | 3 | | | | 2 | | | 6 | 6 | | | | 1 | 1 | 7 | | | | | | | | | 1 | | 1 | | 1 | 1 | 1 | | | | | | | | | 1 | | | | | | | 1 |
| *Rosalina rugosa* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Sagrina pulchella* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Scuturoris procera* | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | 2 | | | | | | | | | | | | | | | | | | | | | | |
| *Spiroloculina atlantica* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 | | 1 | | | | | | | | | | | | | | |
| *Stetsoina minuta* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Textularia candeiana* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Textularia conica* | | | 1 | | | | | 1 | | 3 | | | | | | 3 | 4 | 1 | | | | 1 | 2 | | | | 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Textularia truncata* | | | | | | | | | | | | | | | | | 5 | 2 | | | | | 1 | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Trifarina angulosa* | | | | | | | | | 3 | | | | | | | 3 | | 1 | | | 1 | | 1 | 2 | 3 | 1 | | | | | | 1 | | 1 | 1 | | | | | | | | | | | | | | | | | 1 | 2 | 1 |
| *Triloculina trigonula* | | | | | | | | | | | | | 1 | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Trochammina squamata* | | | 2 | | | | | | 2 | 1 | | | 3 | | | 5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 4 | 1 | 1 |
| *Trochamminula lobata* | | | 1 | 1 | | 1 | | 1 | 2 | 2 | 1 | | | | 1 | | | | 1 | | | | 2 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | 1 |
| *Webbinella concava* | | | | | | 1 | 1 | | | 1 | | | | | | 1 | | 1 | | 1 | | | | | | | 2 | | | | 1 | | | | | | | 2 | | | | | | | | | | | | | | | | | |
| *Wiesnerella auriculata* | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

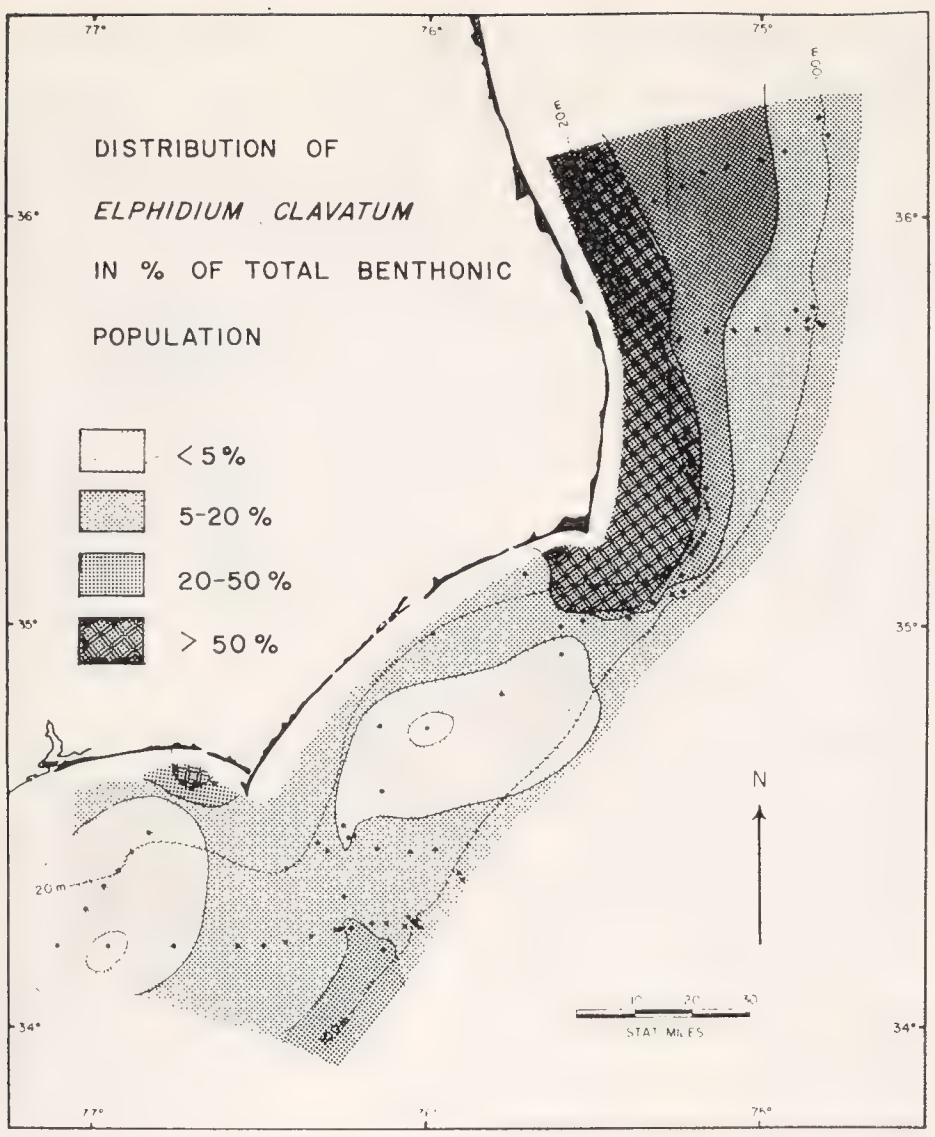


Figure 3

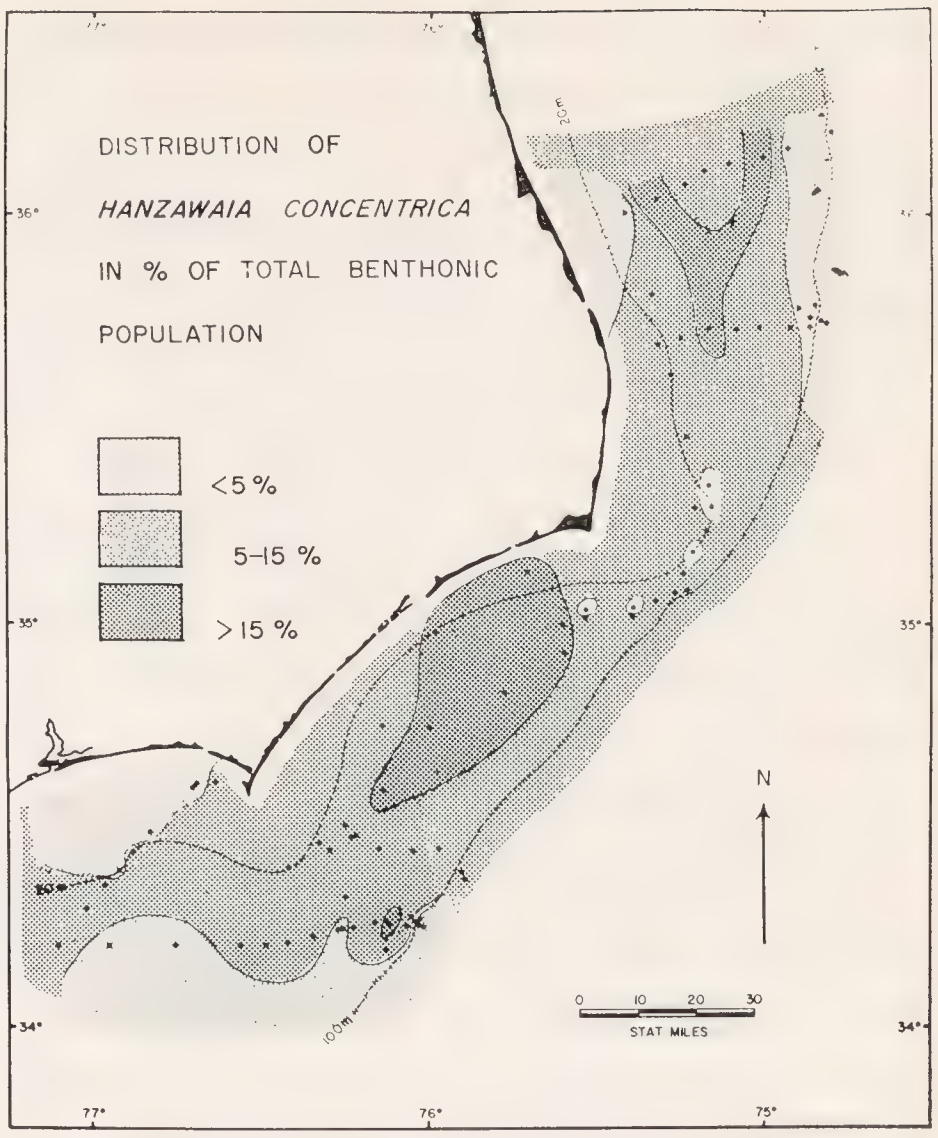


Figure 4

TABLE IIIa PERCENTAGE DISTRIBUTION OF TOTAL PLANKTONIC POPULATION ( N of C. H. )

| STATION NUMBER | 1938 | 2267 | 1992 | 3333 | 3336 | 3337 | 2001 | 2007 | 3332 | 2006 | 1985 | 1997 | 2009 | 2264 | 1994 | 2260 | 2262 | 2010 | 2011 | 2258 | 2256 | 3325 | 3338 | 2254 | 2017 | 2251 | 3324 | 2243 | 2025 | 2247 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DEPTH IN METERS | 19 | 19 | 20 | 20 | 20 | 20 | 22 | 22 | 22 | 23 | 25 | 25 | 26 | 26 | 28 | 32 | 35 | 38 | 38 | 38 | 50 | 50 | 60 | 70 | 80 | 90 | 95 | 110 | 120 | 140 |
| *Candeiana nitida* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | |
| *Globigerina bulloides* | | | | | | | | | | | | | | x | | | | x | x | x | x | x | 45 | 30 | 37 | 41 | 32 | 45 | 43 | 43 |
| *Globigerina dutertrei* | | | | | | | | | | | | | x | | | | | | x | | | x | 1 | 8 | 14 | 5 | 9 | 6 | 11 | 3 |
| *Globigerina inflata* | | | | | x | | | | | | | | | | | | x | x | | | x | x | 9 | 21 | 23 | 20 | 20 | 20 | 23 | 19 |
| *Globigerina pachyderma* | | | | | | | | | | | | | | | | | | | | | | x | | 14 | 3 | 15 | 8 | 13 | 6 | 15 |
| *Globigerina quinqueloba* | | | | | | | | | | | | | | | | | | | | | x | x | 3 | 5 | 3 | 2 | 5 | 4 | 3 | 7 |
| *Globigerinita glutinata* | | | | | | | | | | | | | | | | | | | | | | | 6 | | 1 | 1 | x | 1 | | 1 |
| *Globigerinoides conglobatus* | | | | | | | | | | | | | | | | | | | | | | | | 2 | | | | | 1 | |
| *Globigerinoides ruber* | | | | | x | | | | | | | | | | x | | x | x | | x | x | x | 23 | 14 | 12 | 12 | 19 | 8 | 10 | 8 |
| *Globigerinoides sacculifer* | | | | | | | | | | | | | | | | | | | | | | | 1 | | x | | x | | | x |
| *Globigerinoides trilobus* | x | x | | | | | | | | | | | | | | | | x | | | | x | 4 | 2 | 5 | 1 | 4 | 2 | 2 | 3 |
| *Globorotalia hirsuta* | | | | | | | | | | | | | | | | | | | | | | | | | x | 1 | x | x | x | x |
| *Globorotalia menardii* | | | | | | | | | | | | | | | | | | | | | | | 1 | 4 | 1 | 1 | 1 | 1 | 1 | x |
| *Globorotalia truncatulinoides* | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | | x | x |
| *Hastigerina aequilateralis* | | | | | | | | | | | | | | | | | | | | | | | 1 | | x | x | x | x | 7 | x |
| *Hastigerina pelagica* | | | | | | | | | | | | | | | | | | | | | | | 4 | | | | | | | |
| *Orbulina universa* | | | | | | | | | | | | | | | | | | | | | | | | 1 | 1 | 1 | 1 | | | |
| *Pulleniatina obliqueloculata* | | | | | | | | | | | | | | | | | | | | | x | | | 2 | x | x | x | x | 1 | x |

TABLE IIIb PERCENTAGE DISTRIBUTION OF TOTAL PLANKTONIC POPULATION (South of Cape Hatteras)

| STATION NUMBER | 2145 | 2146 | 2142 | 2307 | 2141 | 2277 | 2139 | 2151 | 2287 | 2137 | 2183 | 2110 | 2127 | 1734 | 1965 | 2116 | 2118 | 2122 | 2123 | 3348 | 1977 | 2117 | 2156 | 2111 | 3269 | 1960 | 2296 | 1963 | 3346 | 3347 | 1737 | 1738 | 1739 | 2109 | 1741 | 2166 | 1975 | 2159 | 3342 | 2108 | 1979 | 2107 | 3340 | 2105 | 2168 | 1750 | 1980 | 3339 | 2171 | 1759 | 2172 | 2104 | 2175 | 1783 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DEPTH IN METERS | 12 | 12 | 15 | 16 | 17 | 18 | 20 | 20 | 20 | 22 | 22 | 23 | 23 | 24 | 25 | 25 | 25 | 25 | 25 | 25 | 26 | 26 | 26 | 28 | 28 | 29 | 29 | 30 | 30 | 30 | 33 | 33 | 33 | 36 | 41 | 42 | 44 | 50 | 50 | 52 | 55 | 57 | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 122 | 125 | 140 | 155 | 159 |
| *Candeiana nitida* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | | x |
| *Globigerina bulloides* | | | | x | | | | | | x | x | | x | | | x | x | x | x | | x | | | x | | x | | | | 35 | 20 | x | x | x | x | x | | x | 36 | 10 | | 5 | x | 33 | 11 | 8 | 2 | x | 16 | 45 | 32 | 3 | 16 |
| *Globigerina dutertrei* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | 1 | | | | x | | x | | 5 | 13 | x | 10 | x | 10 | 10 | 23 | 28 | | 17 | 5 | 7 | 6 | 7 |
| *Globigerina inflata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | | 2 | | | x | | | | | 2 | 2 | | | | 4 | x | x | 1 | | 4 | 5 | 3 | 4 | 4 |
| *Globigerina pachyderma* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 | 1 | | | x | | | | | | 1 | | 3 | | | x | 1 | 5 | | 3 | 1 | | 2 | 2 |
| *Globigerina quinqueloba* | | | | | | | | | | | | | | | | x | | | x | | | | | | | | | | | | | | x | | x | | | x | | 7 | | | | 6 | | x | 1 | | | 1 | 2 | x | x |
| *Globigerinita glutinata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | 1 | | | 10 | | 1 | | | 2 | 1 | 1 | 2 | 1 |
| *Globigerinoides conglobatus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 | x | | | 2 | | | | 1 | | |
| *Globigerinoides ruber* | x | | | | | | x | x | | x | | | x | x | | x | x | x | x | | x | x | | | x | | | x | x | x | 16 | 61 | | x | x | x | | x | x | 31 | 41 | x | 61 | | 10 | 31 | 32 | 55 | x | 44 | 25 | 15 | 60 | 59 |
| *Globigerinoides sacculifer* | | | | | | | | | | | | | | | | | | | x | | | | | | | | | | | | | x | | | | | | | | | | | | | | | 1 | 3 | 2 | | 1 | 1 | | | 1 |
| *Globigerinoides trilobus* | | | | | | | | x | | x | | | x | | | | | | x | | x | x | | | x | | | | | | 41 | 8 | x | x | x | x | | x | 12 | 12 | x | 1 | x | 16 | 15 | 14 | 2 | x | 11 | 14 | 9 | 8 | 7 |
| *Globorotalia hirsuta* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | x | | | | | | 1 | | | | | | 1 | x | | 1 | 1 | 1 | 1 | x |
| *Globorotalia menardii* | | | | | | | | | | | | | | | | | x | | x | | | | | | | | | | | | 2 | 5 | x | | | x | | | 3 | 11 | | 8 | x | 2 | 9 | 5 | 4 | | 4 | 3 | 10 | 4 | 4 |
| *Globorotalia truncatulinoides* | | | | | | | | | | | | | | | | | | | | | x | | | | | | | | | | 2 | | | | | | | | 2 | 5 | | 2 | | 2 | 1 | 1 | 1 | | 4 | 1 | 4 | x | x |
| *Hastigerina aequilateralis* | | | | | | | | | | x | | | | | | | x | x | | | | | | | | | | | | | 2 | 1 | | | x | | | x | | 2 | | 2 | | | 2 | 1 | | | | 3 | | x | 1 |
| *Hastigerina pelagica* | | | | | | | | | | | | | | | x | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 | 2 | x | | | | x | x | x | |
| *Orbulina universa* | | | | | | | | | | | | | | x | | | | | | | | | | | | | | | | | | 1 | | | | | | | | 1 | | 2 | | | 8 | 2 | | 1 | 1 | 3 | x | 2 |
| *Pulleniatina obliqueloculata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 | 2 | | 7 | x | | 2 | 4 | 2 | 2 | | | 3 | 1 | 2 |

(station 2247). South of this area, the number of specimens per sample on the shelf is significantly larger than at the same depths in the northern area, but the general trend prevails. A similar increase in total abundance of benthonic foraminifera with increase in depth was also observed by Bandy (1954, 1956) in the Gulf of Mexico, and by Walton (1955) and Uchio (1960) on the west coast of the U.S. Bandy ascribes this increase to higher sedimentation rates near shore and Walton (1955) and Uchio (1960) show that large concentrations of benthonic specimens occur in areas of extremely slow sedimentation.

The same explanation applies apparently to the present study area. As previously mentioned, only the nearshore sediments of the Carolina shelf are regarded as recent, and the major portion of the shelf is thought to expose relict Pleistocene sediment.

Formation of authigenic minerals (glauconite, phosphorite) and strong iron staining are generally considered diagnostic of low sedimentation rates. These minerals occur abundantly on the central and outer portions of the North Carolina shelf. Foraminiferal tests appear highly susceptible to such

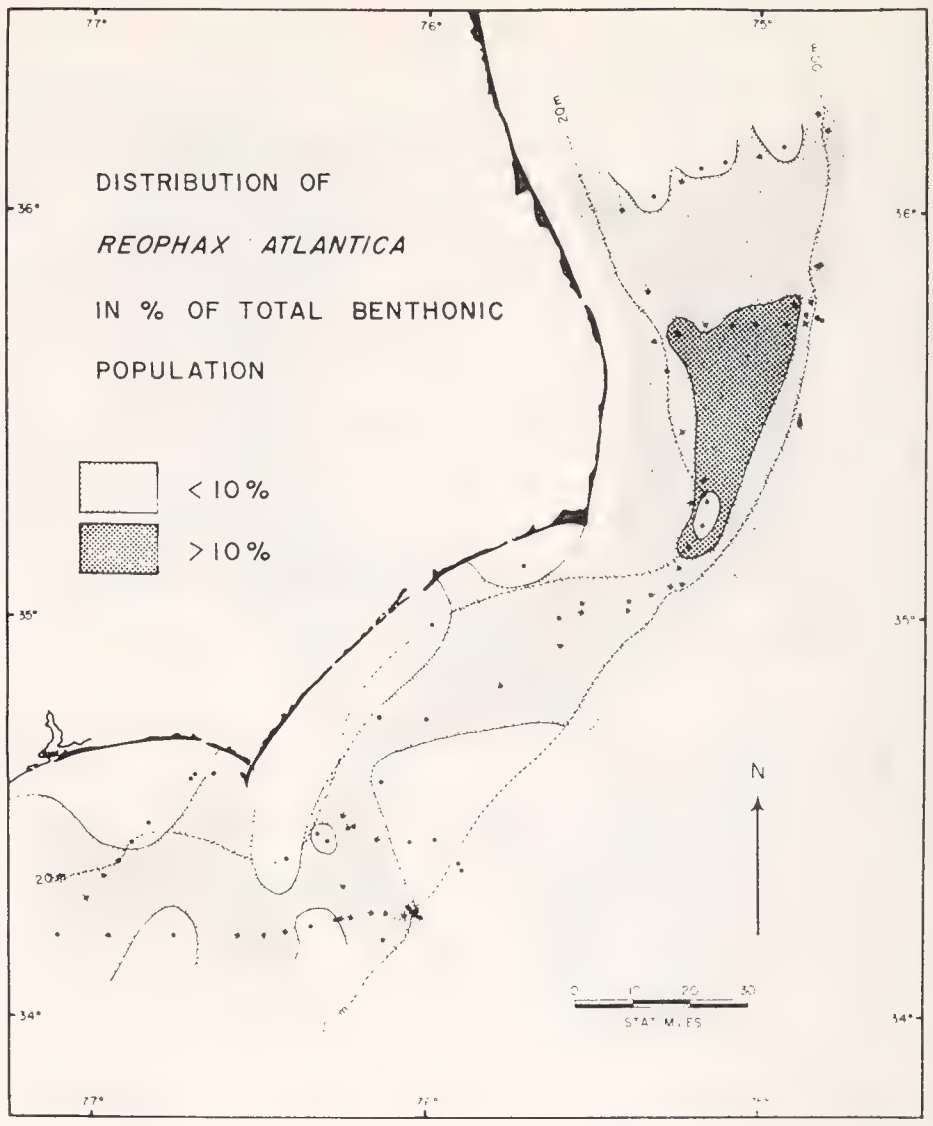


Figure 5

chemical alteration and figure 17 shows the distribution of altered tests, which have been either glauconitized, phosphatized, iron stained or are covered by a thick crust of secondary glassy calcite. Such specimens are

TABLE IV. Thanato-coenosis divisions of the North Carolina Continental Shelf.

| | | NEAR SHORE | CENTRAL SHELF | SHELF EDGE--UPPER CONT. SLOPE |
|---|---|---|---|---|
| VIRGINIAN | I | Elphidium clavatum 50% | Elphidium clavatum 50%-15%<br>Hanzawaia concentrica 10%<br>Reophax atlantica 10%<br>Webbinella concava 5%<br>Guttulina lactea 5% | Islandiella subglobosa 10%<br>Bulimina marginata 10%<br>Lenticulina orbicularia 5%<br>Cibicides pseudoungerianus 5%<br>Trifarina angulosa 2%<br>Rosalina rugosa (patchy) 4%<br>Cibicides bradyi (shallow in S) 5% |
| CAROLINIAN | II RALEIGH BAY | | Hanzawaia concentrica 15%<br>Reophax atlantica 10%<br>Peneroplis proteus 10%<br>Quinqueloculina seminula 10%<br>Asterigerina carinata 6%-10%<br>Reophax scorpiurus 5%<br>Quinqueloculina compta 4% | Lenticulina orbicularis 4%<br>Cibicides pseudoungerianus 6%<br>(shallow in S)<br>Amphistegina lessonii 1% - 8% |
| | III ONSLOW BAY | | Peneroplis proteus 15%<br>Placopsilina confusa 20%<br>Quinqueloculina seminula 20%<br>Quinqueloculina lamarckiana 5%<br>Quinqueloculina compta 5%<br>Asterigerina carinata 6%<br>Reophax scorpiurus 5% | Islandiella subglobosa 5%<br>Lenticulina orbicularis 2%<br>Amphistegina lessonii 1% -16%<br>Trifarina angulosa 4% |

most abundant in the southern portion of the area and their abundance increases with distance from shore. The northern section of the area and the near shore area south of Cape Hatteras is free of altered individuals. Thus it appears that the alteration is caused by Gulf Stream water, either by the Gulf Stream directly along the edge of the shelf or, on the shelf proper, by Carolina Coastal water, derived from Gulf Stream water. The lack of altered specimens on the northern shelf need not imply that those sediments are not relict, but rather that Virginian Coastal water does not induce these chemical changes.

Relative sedimentation rates have also been shown to be indicated by the ratio of living population to total population (Phleger, 1955). This is based on the assumption that the total living population (standing crop) is a measure of test production in any given area. In areas of high sedimentation the abundance of tests in the sediment will be lowered, whereas in areas of low sedimentation rates, the tests will be concentrated. The central shelf is generally the area which carries the highest number of living specimens (fig. 18). If the assumption that the standing crop is a measure of the production of tests is valid, then it appears from figure 19 that the distribution of areas of high,

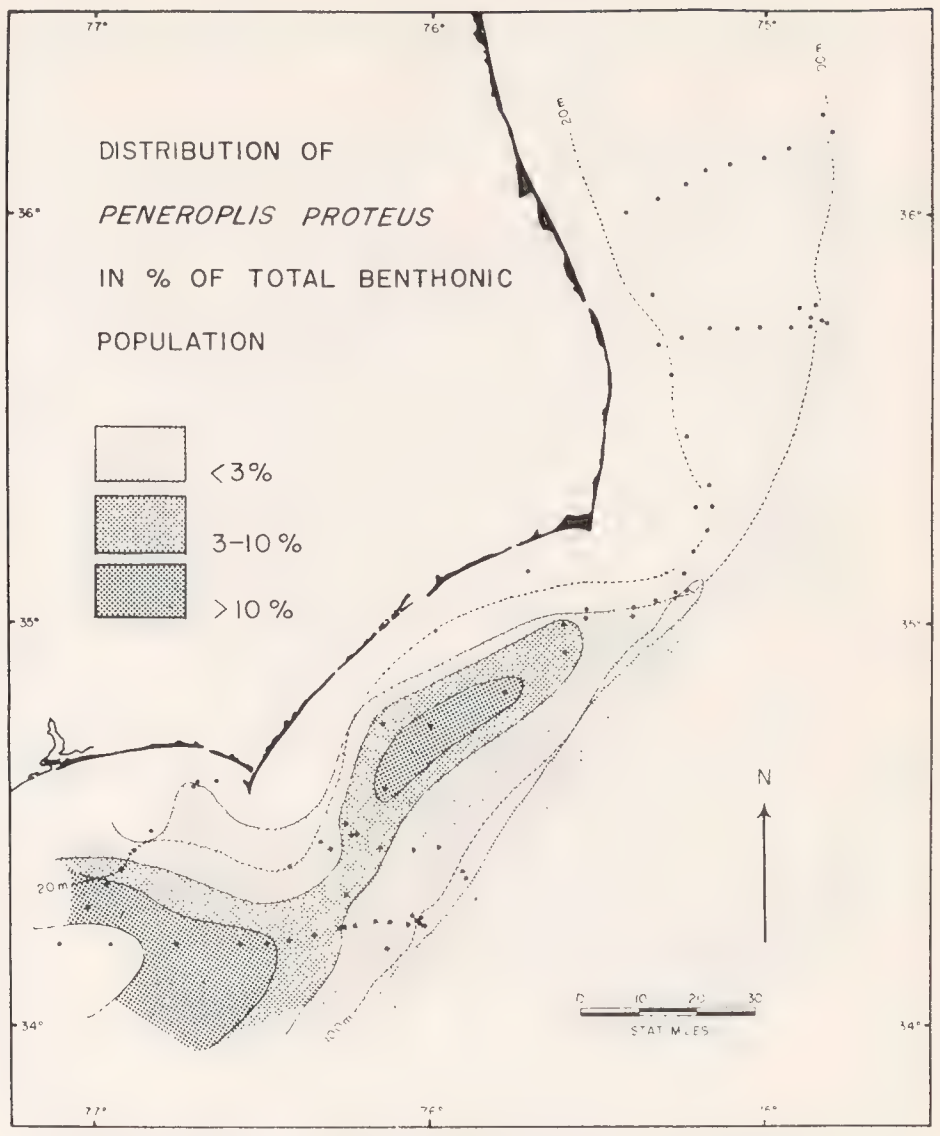


Figure 6

medium, and low relative sedimentation is not what would be expected on the basis of sediment distribution and total benthonic populations. Good agreement with the expected pattern of sedimentation occurs along the outer shelf—shelf edge north of Cape Hatteras, and on the outer portions of the

TABLE V
FAUNAL DIVERSITY INDICES

| Sample Number | Diversity Index | Sample Number | Diversity Index | Sample Number | Diversity Index | Sample Number | Diversity Index |
|---|---|---|---|---|---|---|---|
| 1734 | 4.83 | 2006 | 5.95 | 2138 | 16.39 | 2261 | 6.88 |
| 1737 | 19.56 | 2008 | 4.84 | 2139 | 5.71 | 2264 | 5.38 |
| 1738 | 23.14 | 2004 | 6.12 | 2140 | 12.15 | 2267 | 1.98 |
| 1739 | 9.72 | 2010 | 7.78 | 2141 | 10.12 | 2277 | 8.28 |
| 1741 | 16.48 | 2011 | 11.58 | 2145 | 9.63 | 2287 | 13.38 |
| 1750 | 33.39 | 2017 | 12.79 | 2146 | 2.19 | 2296 | 21.39 |
| 1759 | 12.44 | 2025 | 15.65 | 2150 | 15.68 | 2308 | 6.65 |
| 1783 | 24.01 | 2104 | 35.58 | 2156 | 13.03 | 3269 | 7.08 |
| 1960 | 21.74 | 2105 | 10.21 | 2159 | 10.01 | 3324 | 11.55 |
| 1963 | 17.41 | 2107 | 13.38 | 2166 | 17.14 | 3325 | 10.68 |
| 1965 | 7.66 | 2108 | 22.35 | 2168 | 30.60 | 3332 | 3.31 |
| 1974 | 9.07 | 2109 | 10.89 | 2171 | 8.92 | 3333 | 4.50 |
| 1977 | 19.78 | 2110 | 8.29 | 2172 | 19.22 | 3336 | 7.56 |
| 1979 | 15.14 | 2111 | 20.69 | 2175 | 19.43 | 3337 | 8.50 |
| 1980 | 25.24 | 2116 | 18.58 | 2245 | 10.41 | 3338 | 4.34 |
| 1983 | 3.55 | 2117 | 12.58 | 2246 | 10.75 | 3339 | 18.32 |
| 1985 | 3.24 | 2118 | 15.19 | 2251 | 11.79 | 3340 | 11.47 |
| 1992 | 8.85 | 2122 | 9.47 | 2254 | 13.50 | 3342 | 1.88 |
| 1994 | 2.61 | 2123 | 9.64 | 2256 | 12.98 | 3346 | 2.28 |
| 1997 | 1.55 | 2124 | 8.08 | 2257 | 12.72 | 3347 | 14.04 |
| 2001 | 4.19 | 2137 | 20.14 | 2259 | 9.03 | 3348 | 9.22 |

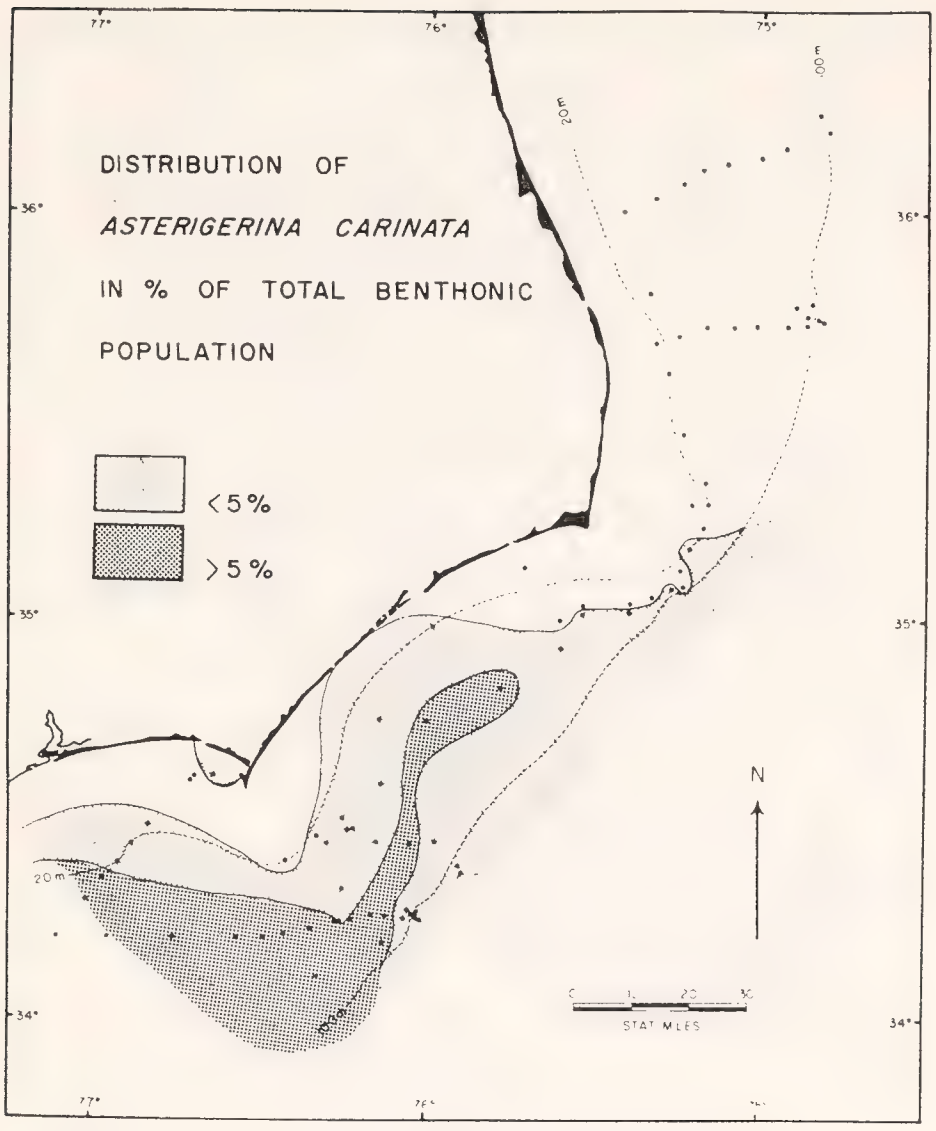


Figure 7

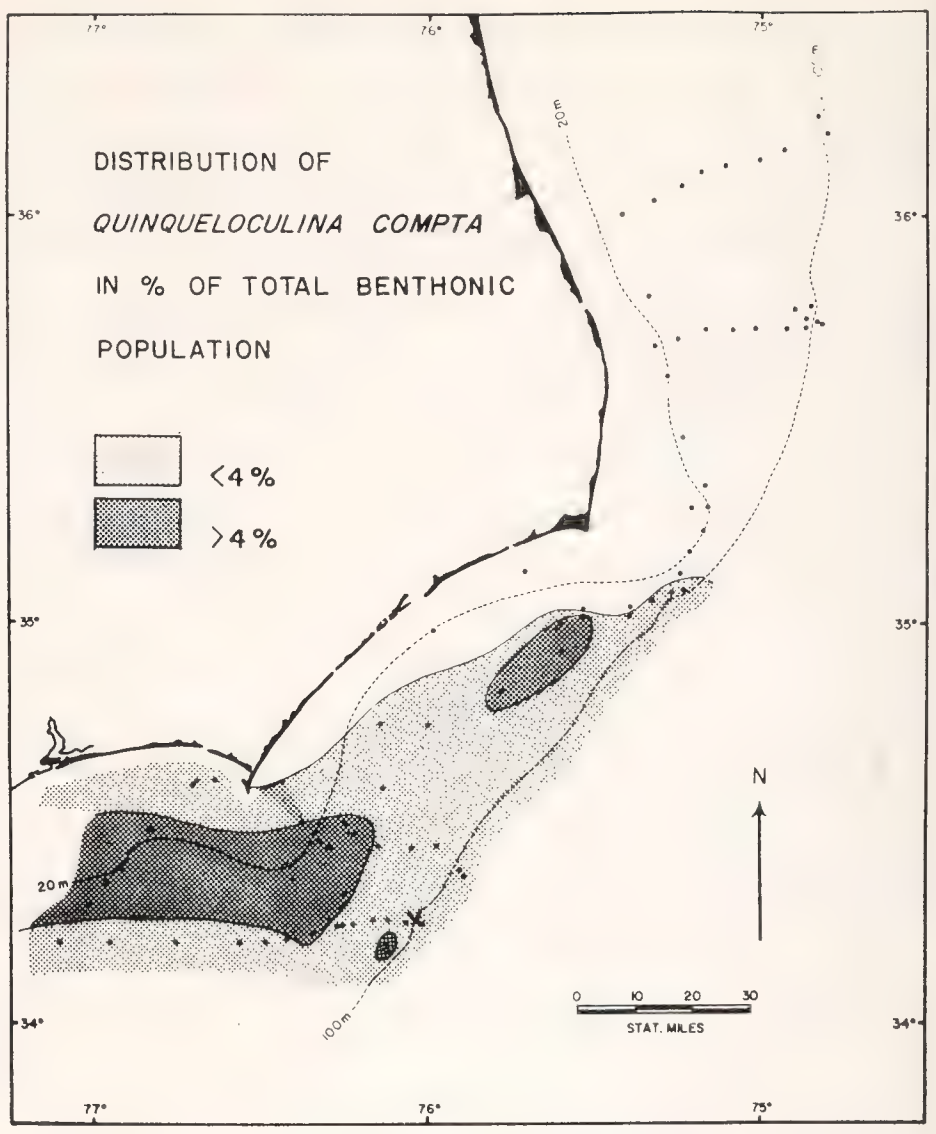


Figure 9

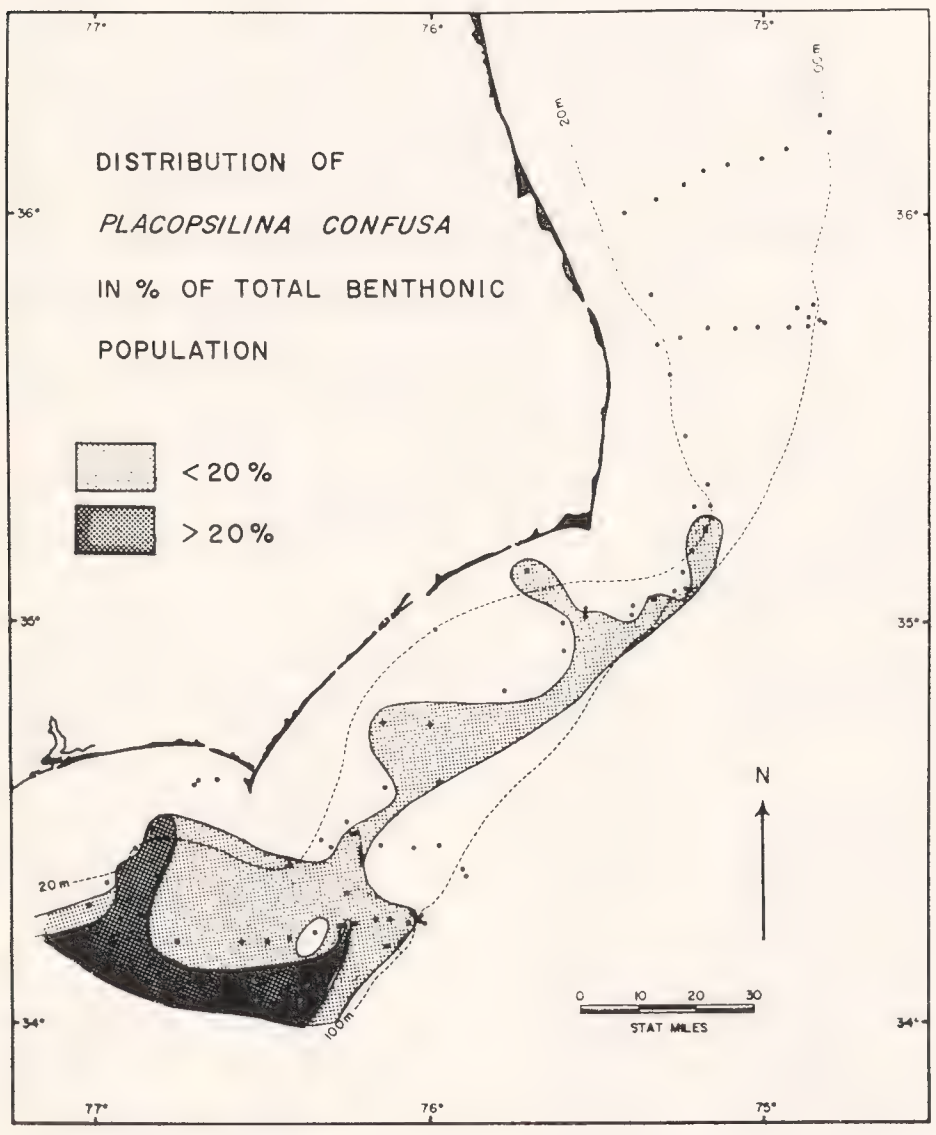


Figure 8

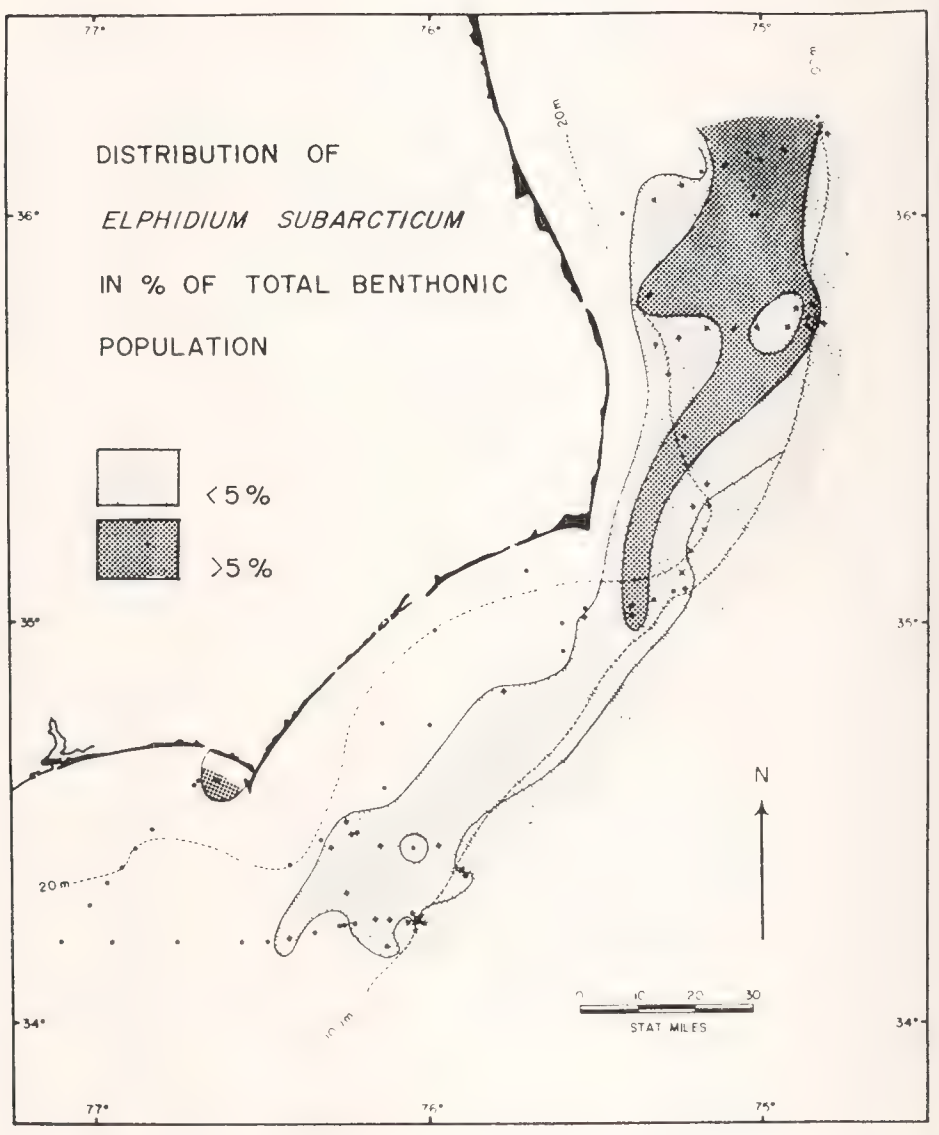


Figure 10

central shelf and the outer shelf south of Cape Hatteras, where very low sedimentation rates are indicated by values of less than 5% of living foraminifera. Also in good agreement is the nearshore area and inner portion of the central shelf between Cape Hatteras and Cape Lookout, where the percentage of living foraminifera decrease with distance from shore. Unexpectedly high percentages are found, however, on the central shelf north of Cape Hatteras and on certain portions of the central shelf south of Cape Lookout. These areas are covered by relatively coarse-grained sediment which is generally assumed to be relict. The most likely explanation for these anomalies may be that

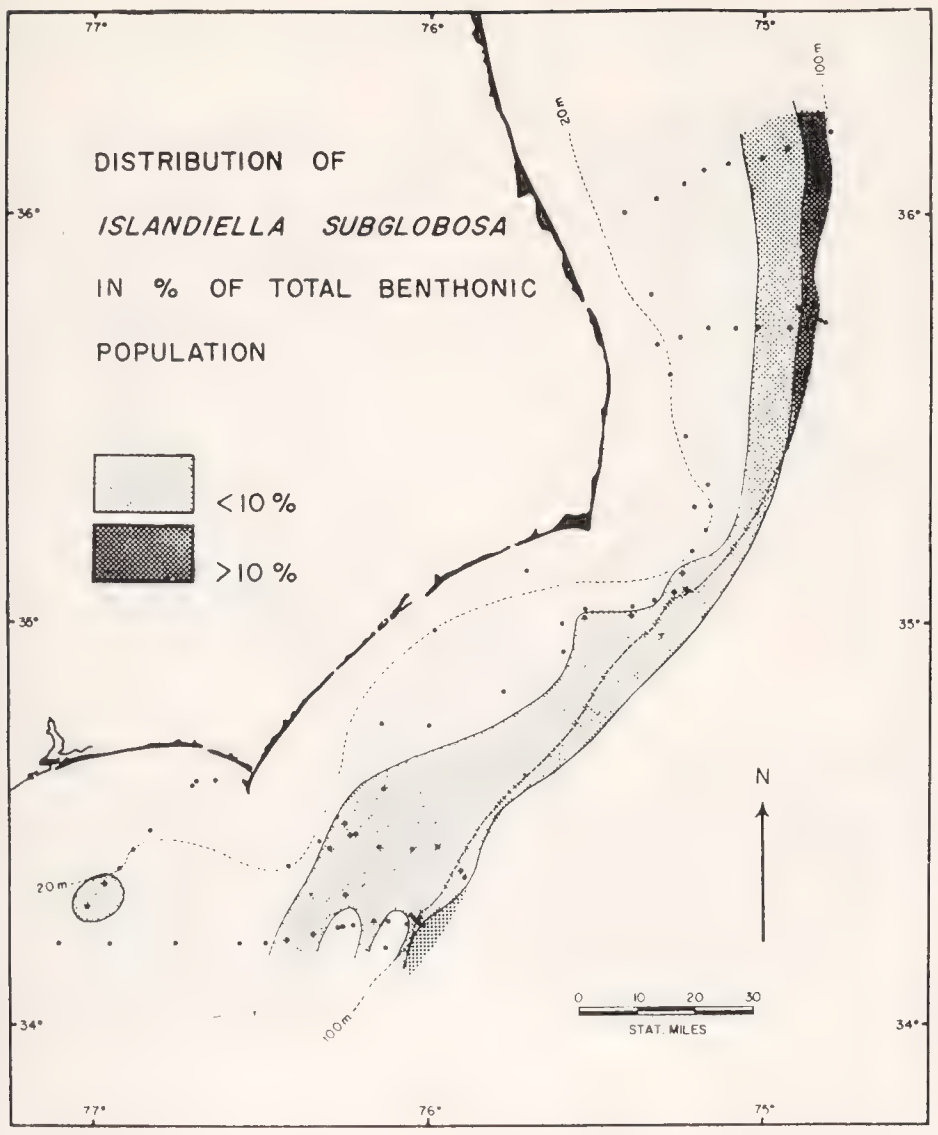


Figure 11

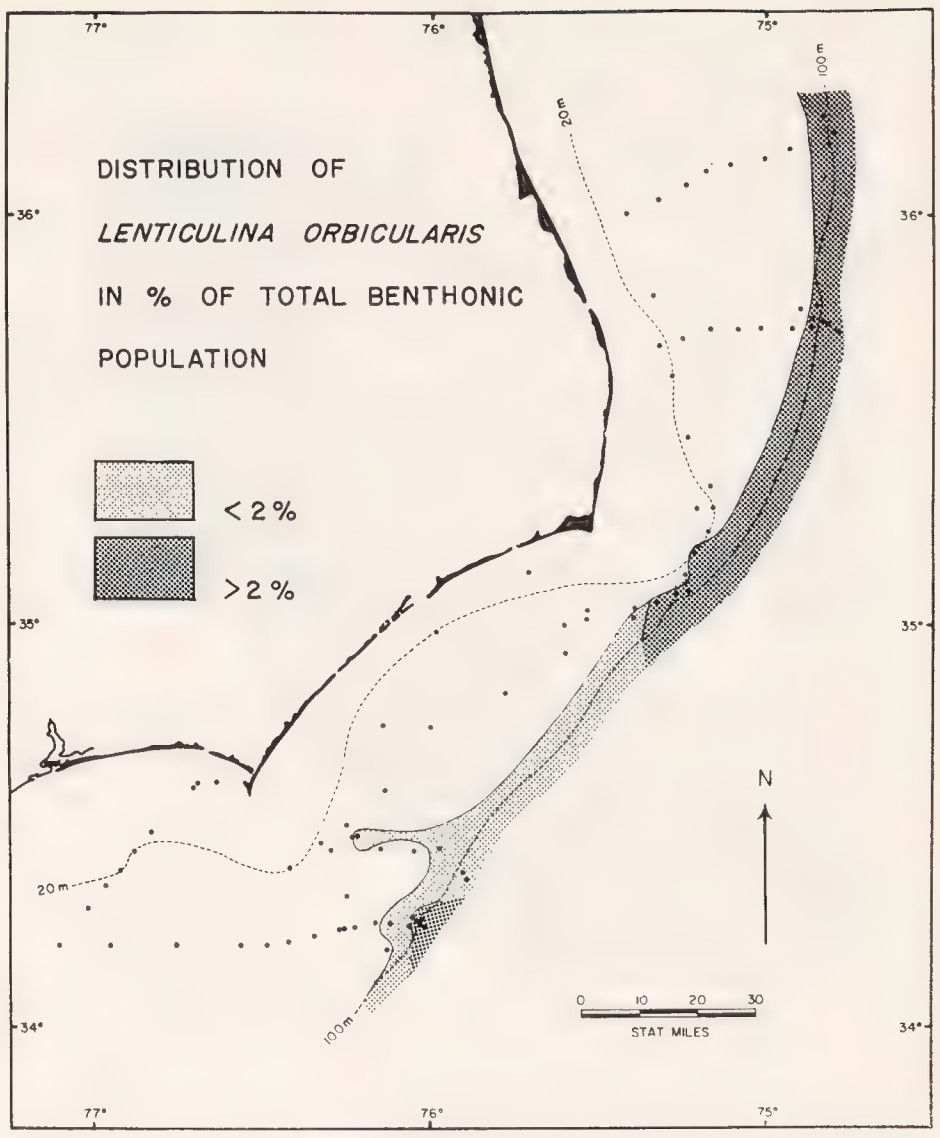


Figure 13

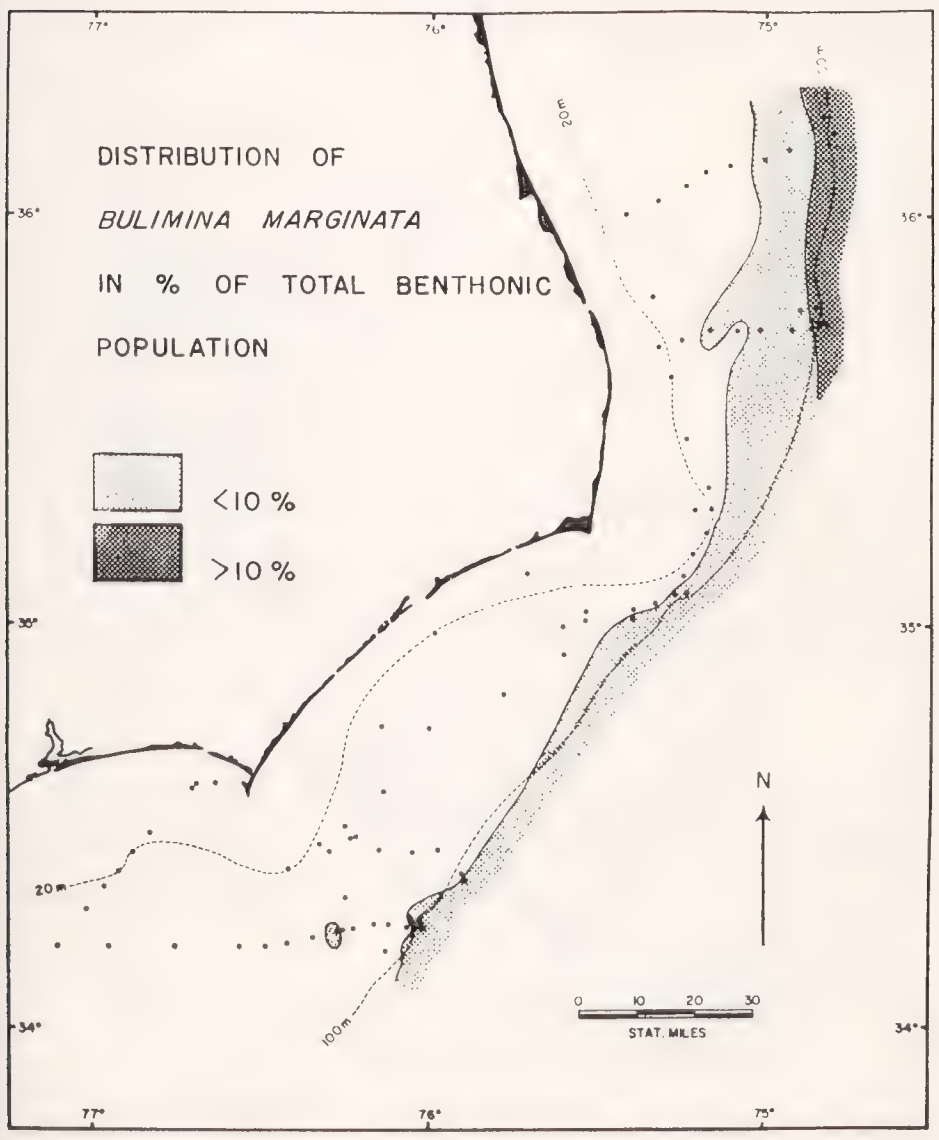


Figure 12

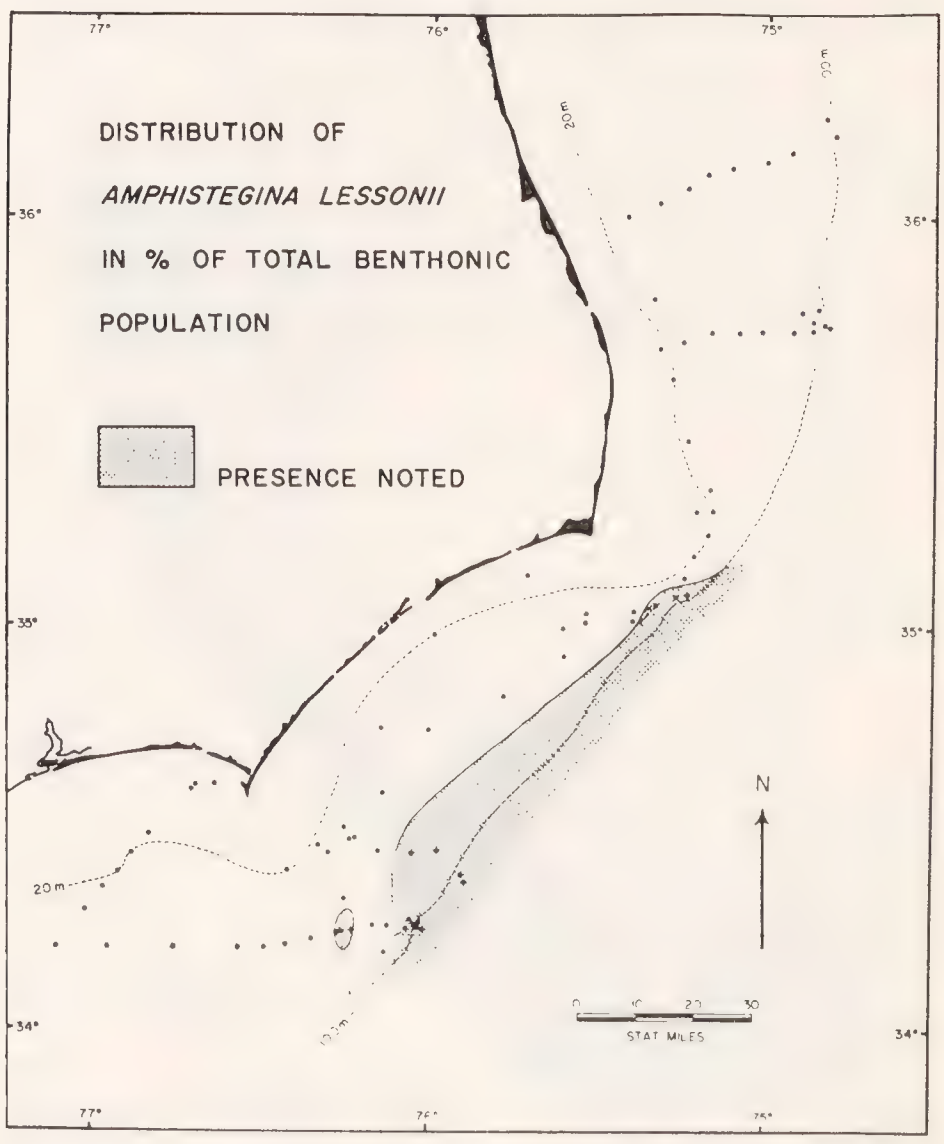


Figure 14

the number of living specimens encountered may not directly reflect the rate of production of empty tests. That is, species living on the central shelf may have longer life cycles, or recognition of living specimens may not have been accurate. As an example, the organic cement of the tests of certain arenaceous species, especially *Reophax atlantica,* is also stained by Rose Bengal and thus empty tests may have been confused with living specimens. *Reophax atlantica* is very abundant on the central shelf (fig. 5).

## E. Changes in Sealevel

Comparison of the depth ranges of living and total populations is difficult because

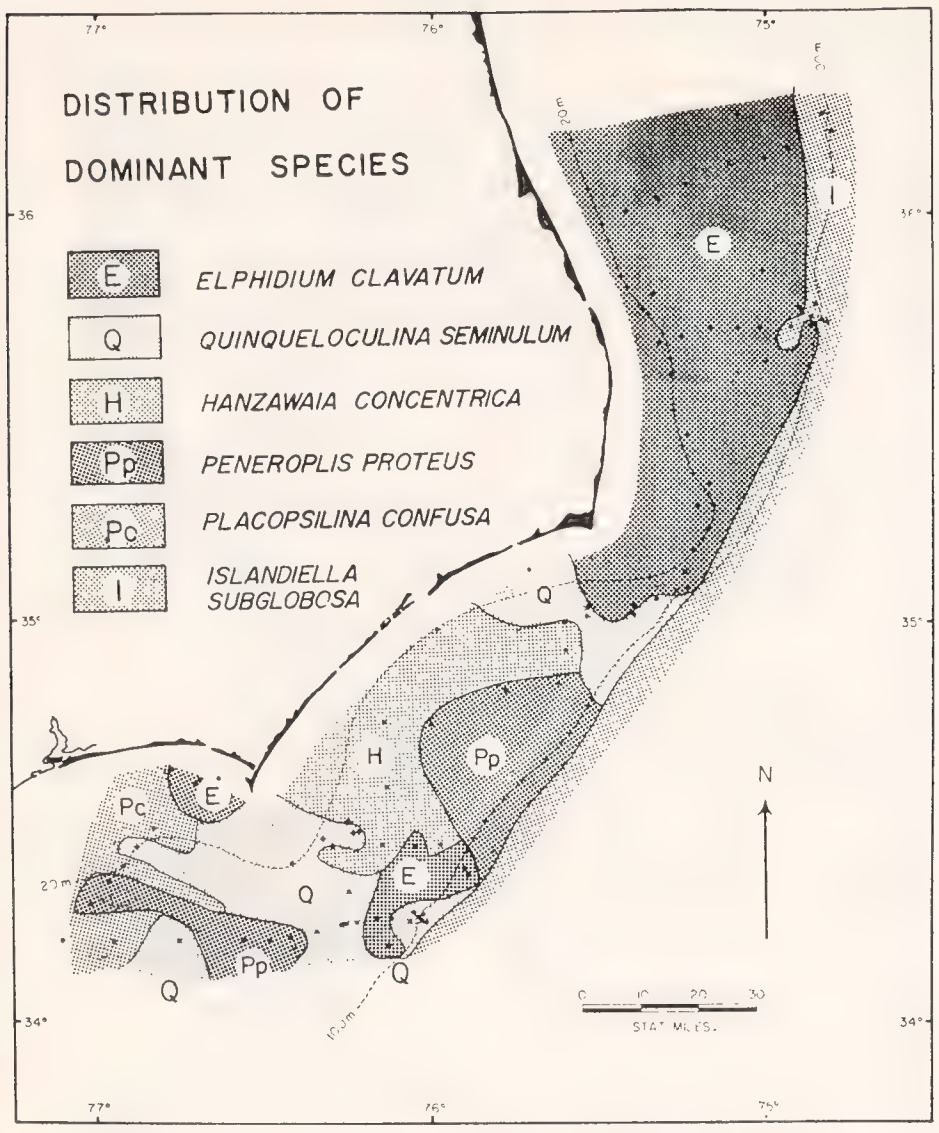


Figure 15

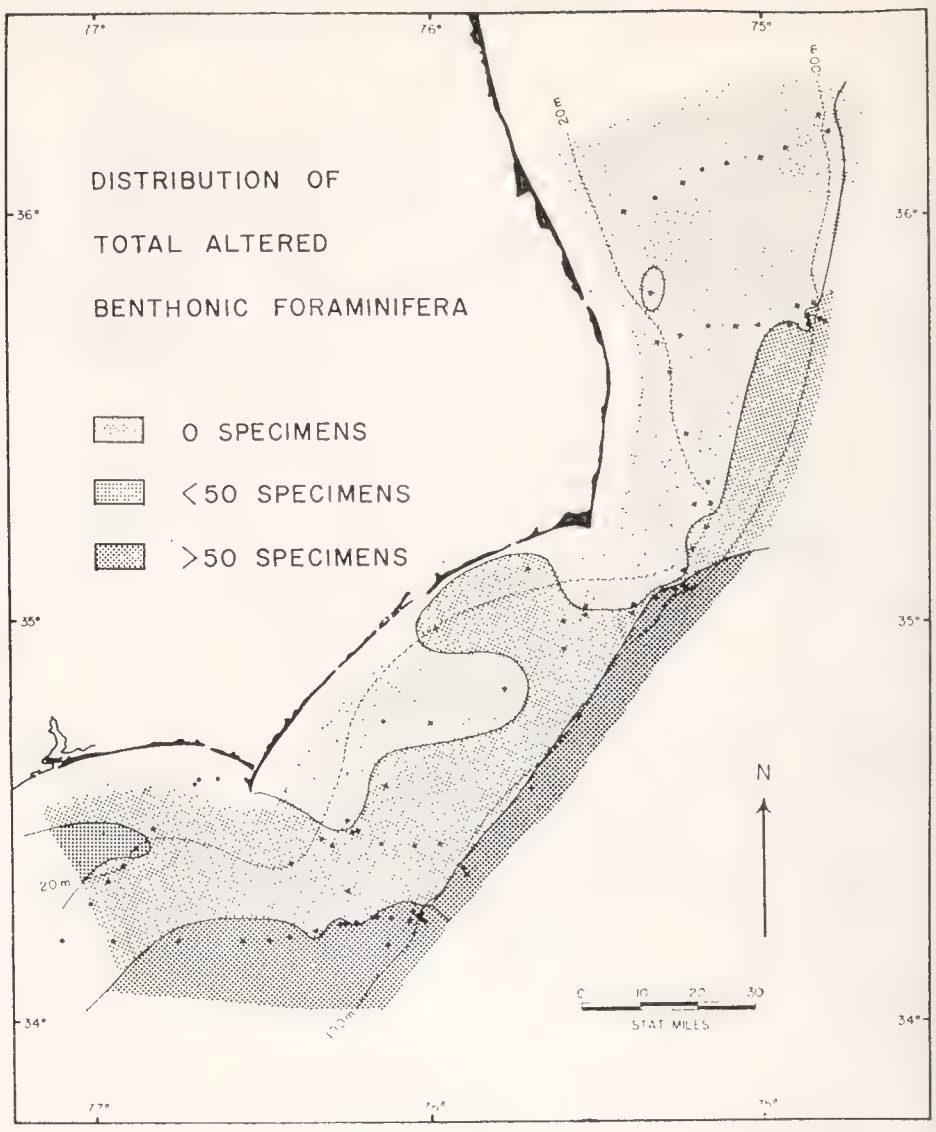


Figure 17. Distribution of total number of altered benthonic foraminifera per cubic centimeter of sample

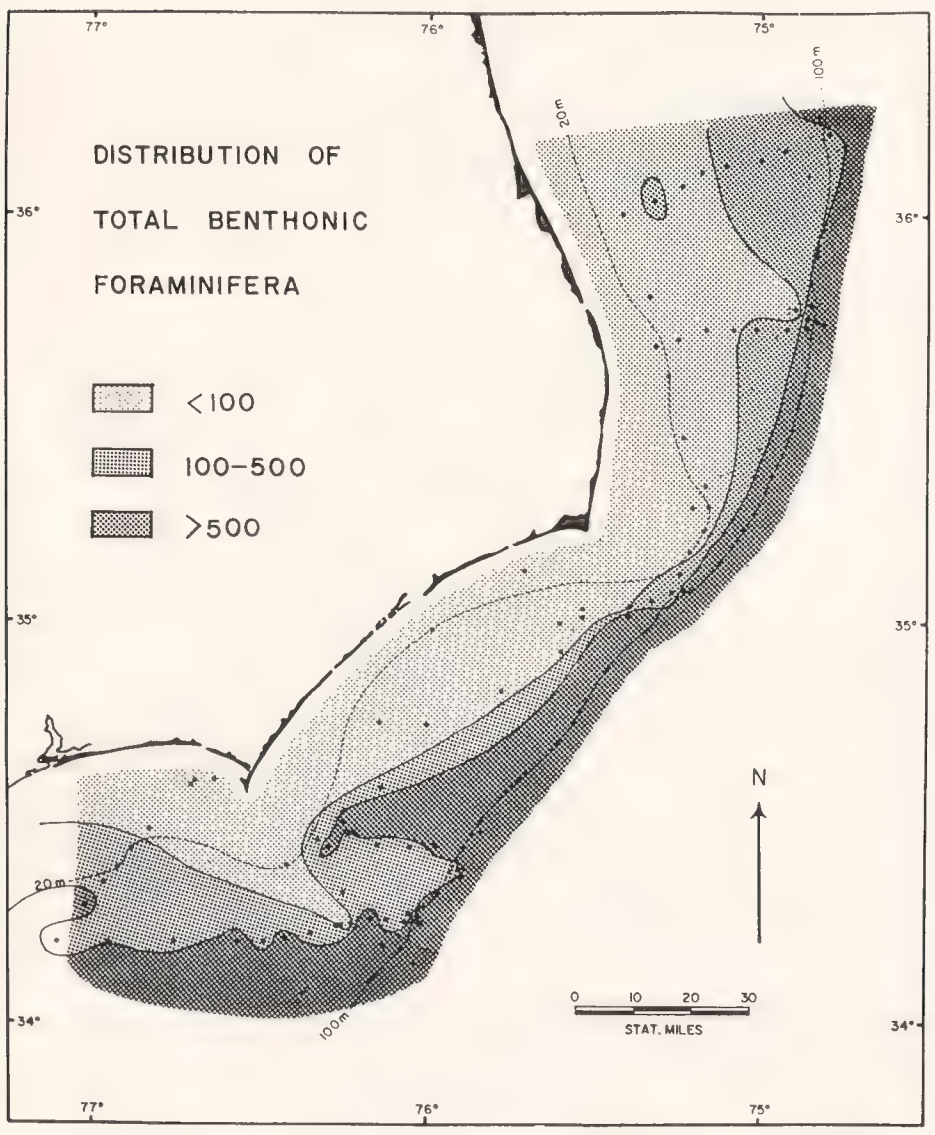


Figure 16. Distribution of total benthonic foraminifera, expressed in number of specimens per cubic centimeter of sample

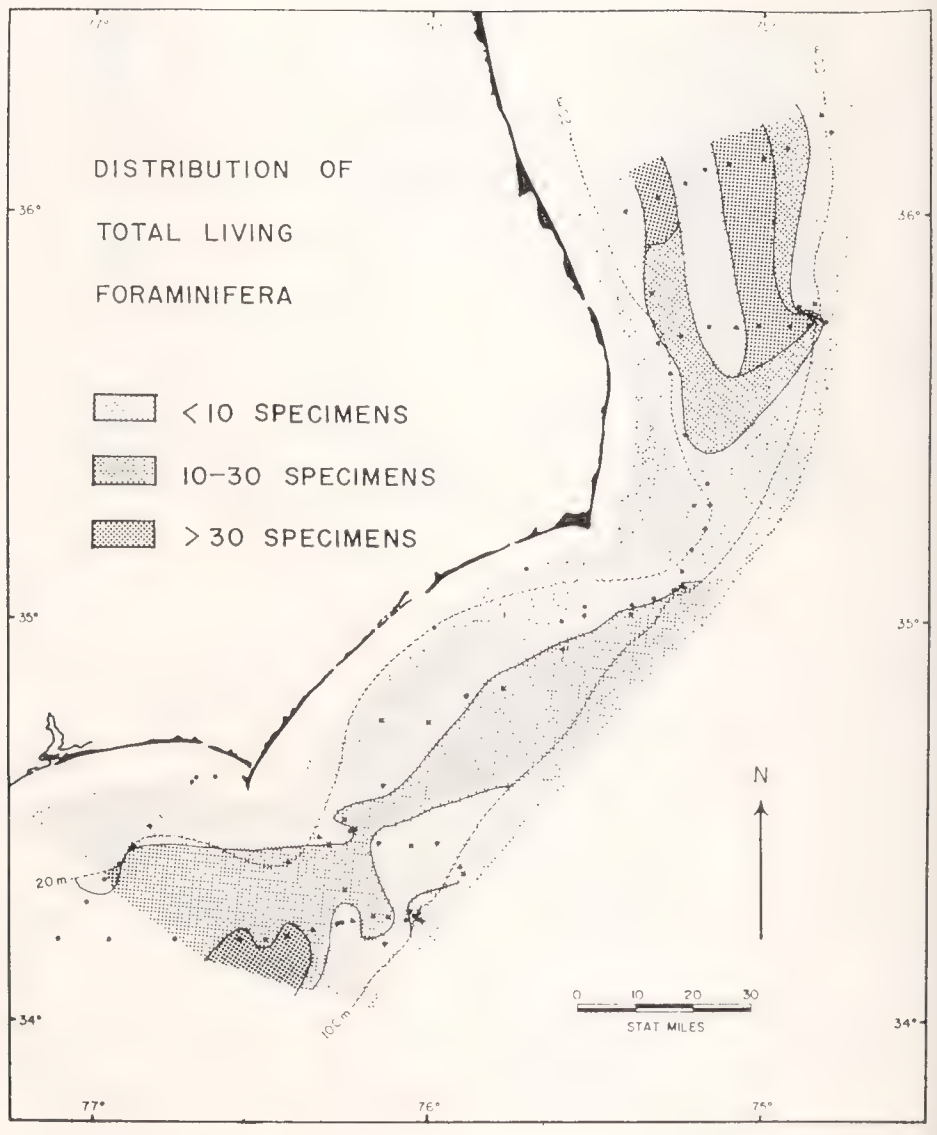


Figure 18. Distribution of total living foraminifera, in specimens per cubic centimeter of sample

very few living specimens were recorded. Thus, especially in the case of less abundant species, the absence of living representatives may result from their scarcity (non-recovery) or from real absence. Comparison can be qualitative only. It has been recognized earlier (Phleger, 1956; Uchio, 1960) that dead individuals frequently occur at greater depths than living populations. This type of distribution may be explained either by

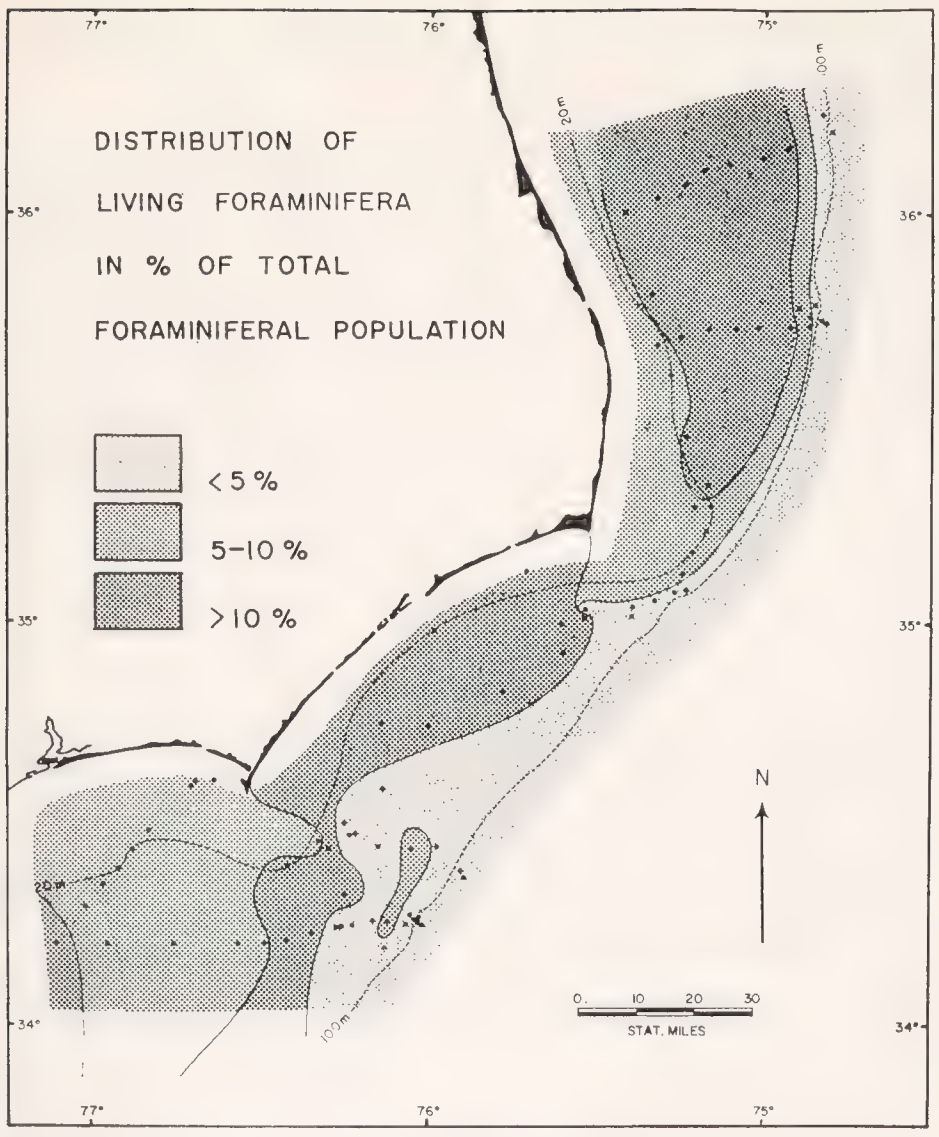


Figure 19

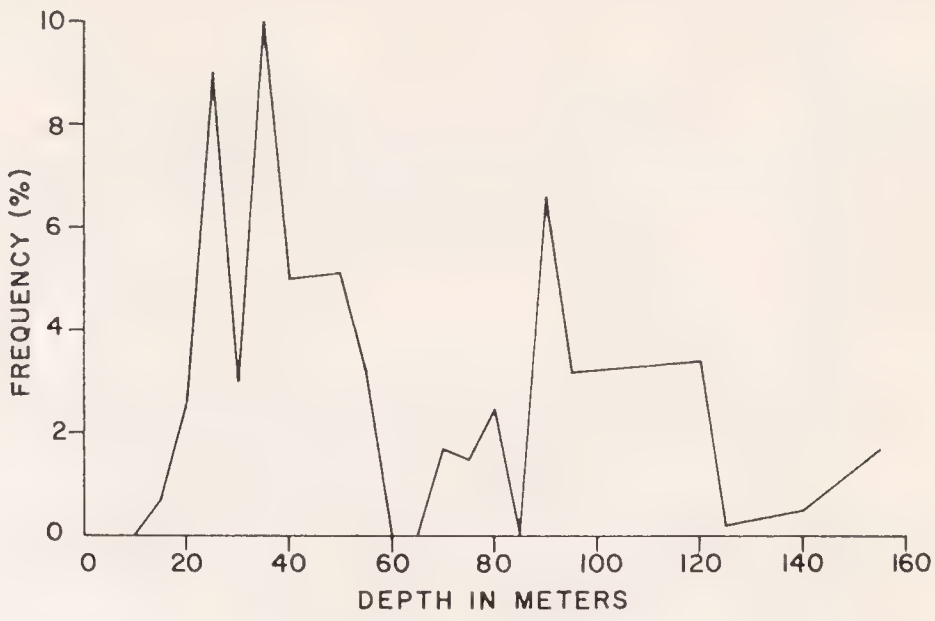


Figure 22. Frequency distribution of *Asterigerina carinata.*

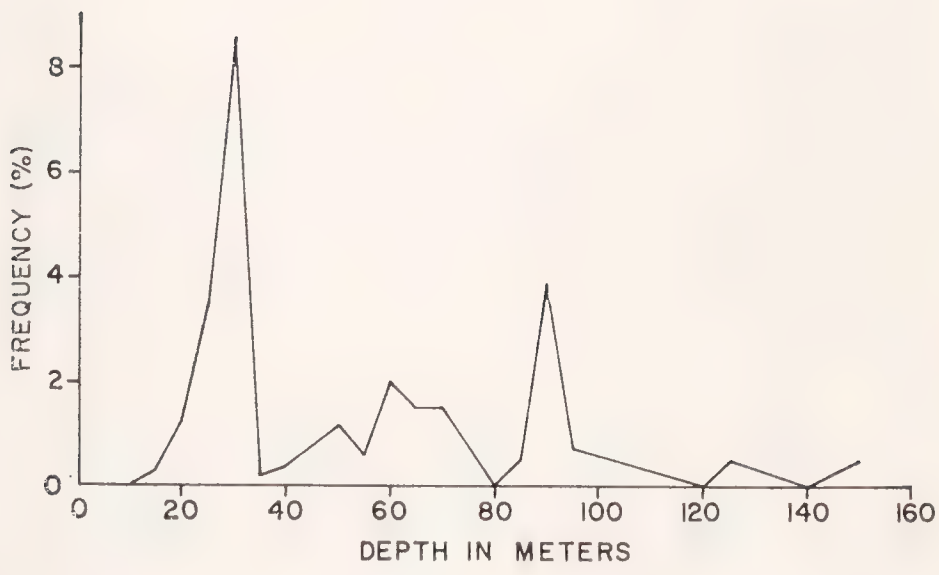


Figure 20. Frequency distribution of *Reophax atlantica.*

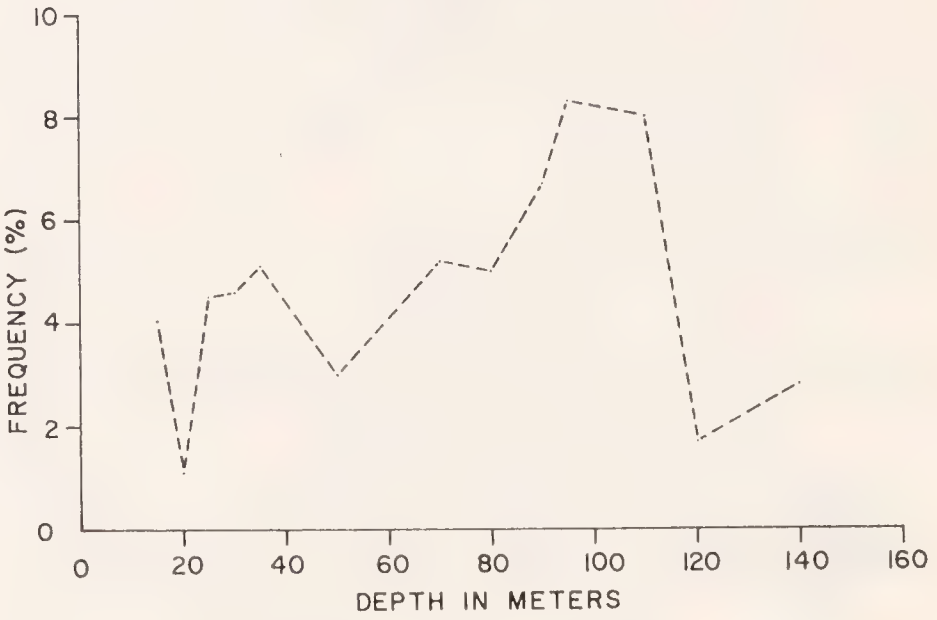


Figure 23. Frequency distribution of *Elphidium subarcticum.*

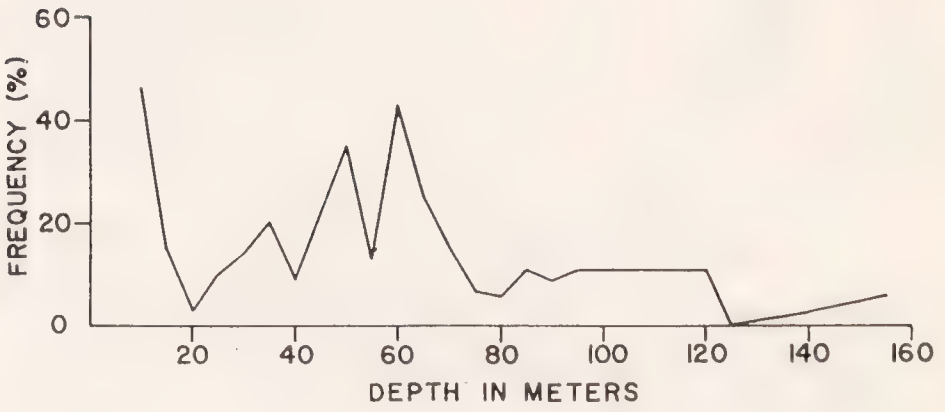


Figure 24. Frequency distribution of *Elphidium clavatum.*

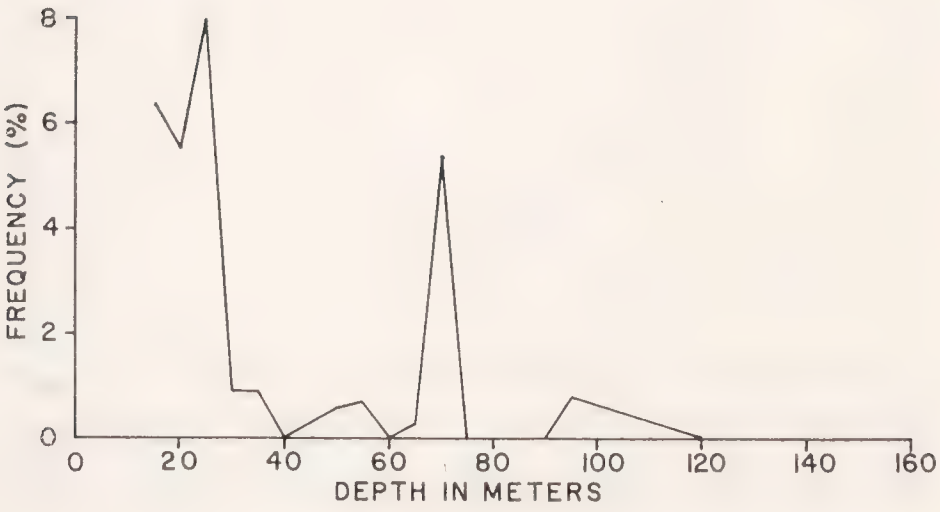


Figure 21. Frequency distribution of *Placopsilina confusa.*

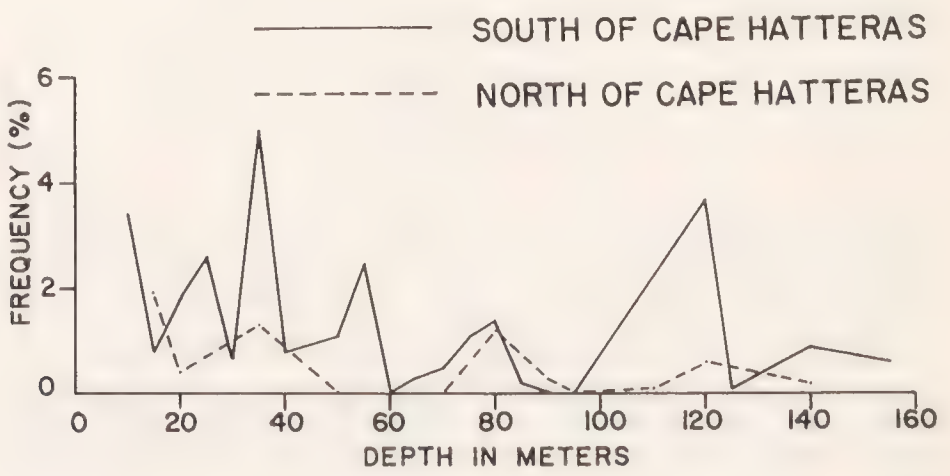


Figure 25. Frequency distribution of *Quinqueloculina jugosa.*

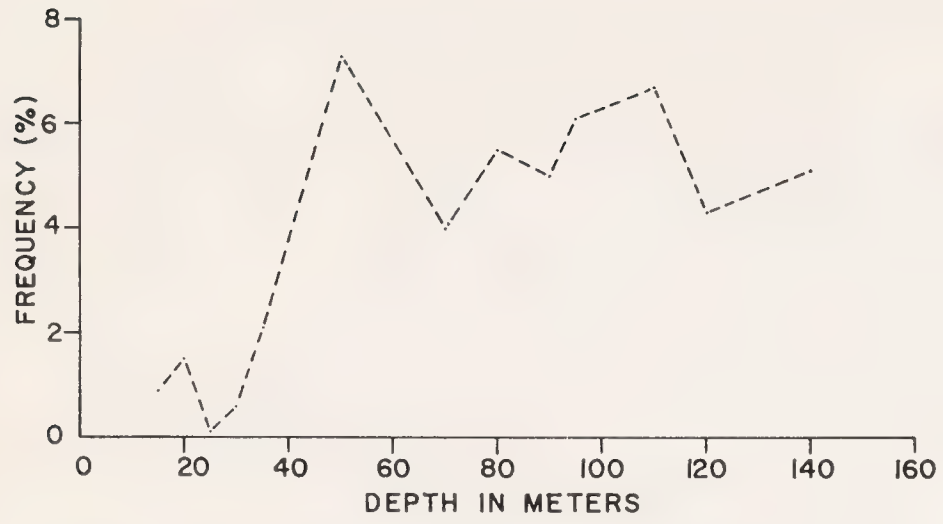


Figure 26. Frequency distribution of *Cibicides bradyi.*

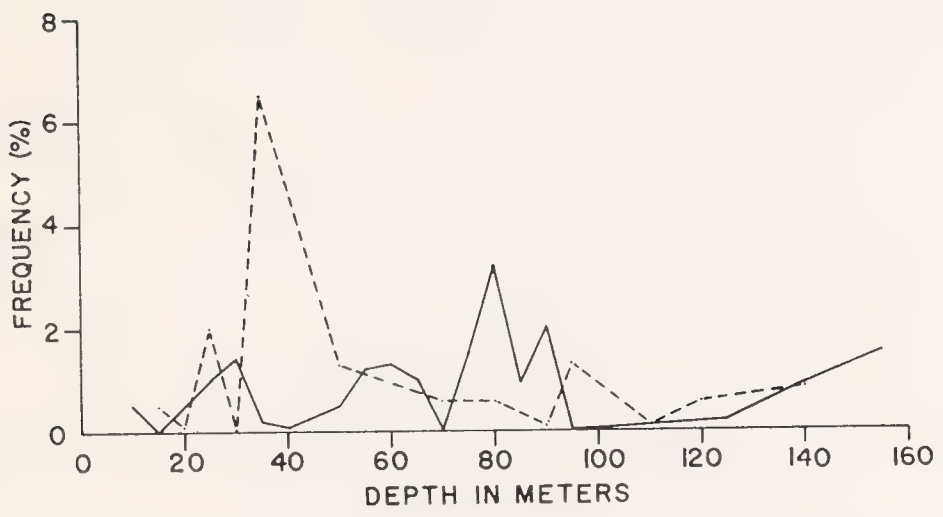


Figure 27. Frequency distribution of *Planulina exorna.*

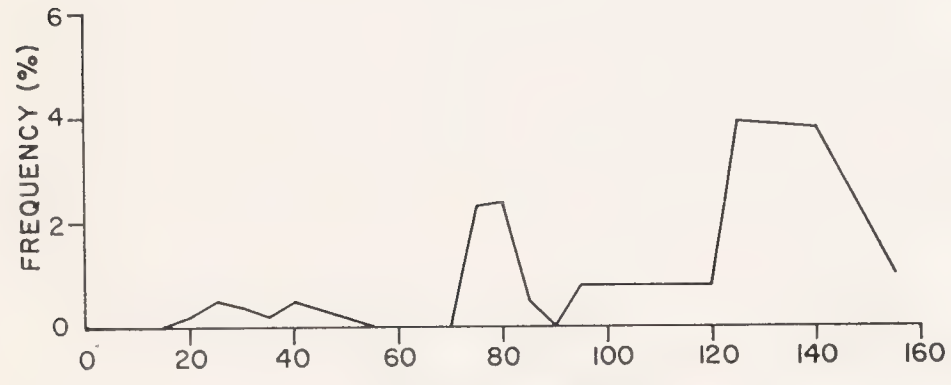


Figure 28. Frequency distribution of *Neoconorbina terquemi.*

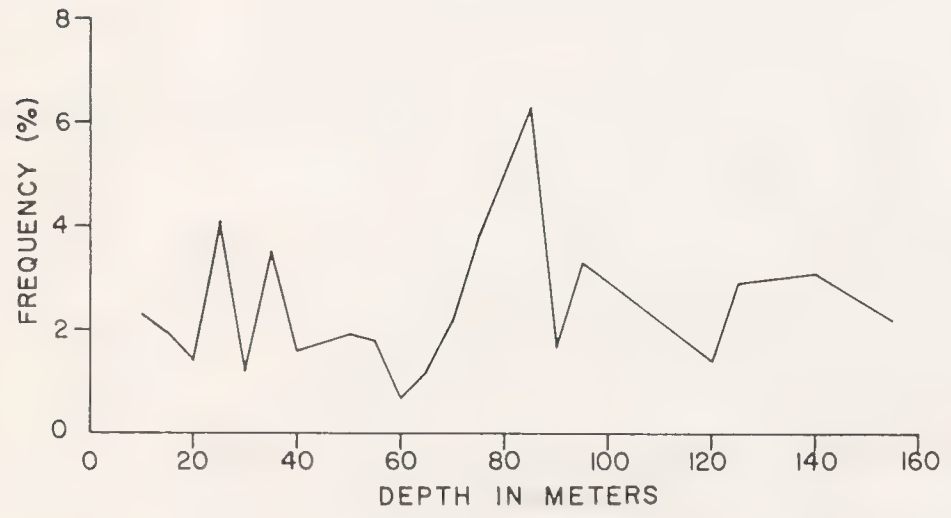


Figure 29. Frequency distribution of *Textularia conica.*

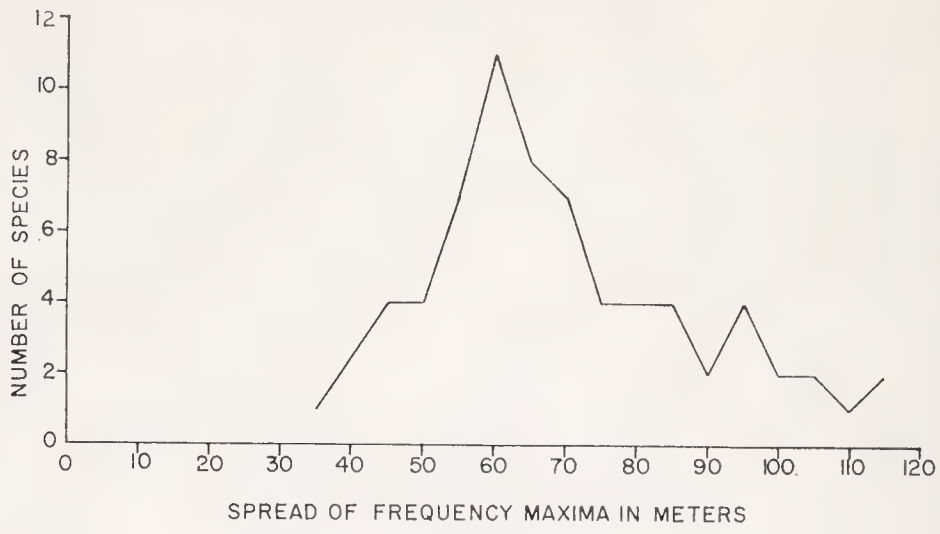


Figure 30

downslope transportation of empty tests, or records of relict shallow assemblages from a time of lower sealevel.

The frequency diagrams (figures 20 to 29) of several of the more abundant species indicate that this general depth distribution pattern recognized by Phleger (1956) and Uchio (1960) also holds for the North Carolina shelf fauna; living specimens are either more abundant or are confined to the shallow portion of the total depth range. Also, very pronounced maxima are apparent in the frequency distribution of the species. The shallowest maximum normally coincides with the area having the greatest number of living individuals, and is thought to have been produced there under present conditions. Most species also exhibit secondary or even tertiary maxima in deeper water, normally with no living representatives at this depth. These deeper water maxima probably were produced when sea level was lower and conditions were similar to those now found at shallower depths. Figure 30 shows the relative positions of the maxima for several species. The shallowest peak of each species is taken as zero and the position of the secondary peaks are recorded accordingly. The greatest number of secondary maxima occurs 60 meters below the primary maximum for the same species and the resulting curve is skewed in the direction of greater depth. This value probably represents lowered sealevel during the last Pleistocene glaciation stage. The skewness of the curve may have been caused by net downslope movement of tests in the area of the shelf edge—upper continental slope, where gradients exceed 100 feet per mile. Very similar values for the lowering sealevel have been reported on the basis of oölite occurrences on

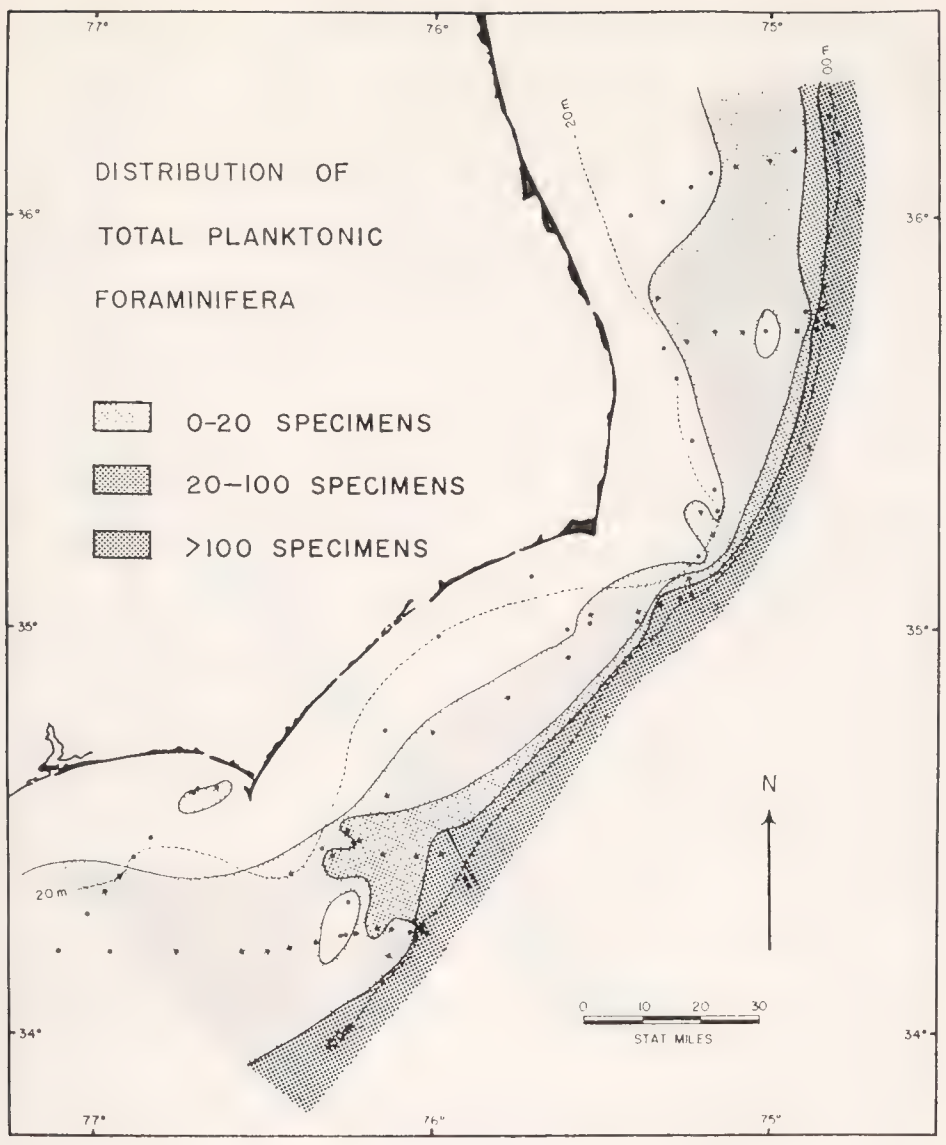


Figure 31. Distribution of total planktonic foraminifera, in specimens per cubic centimeter of sample.

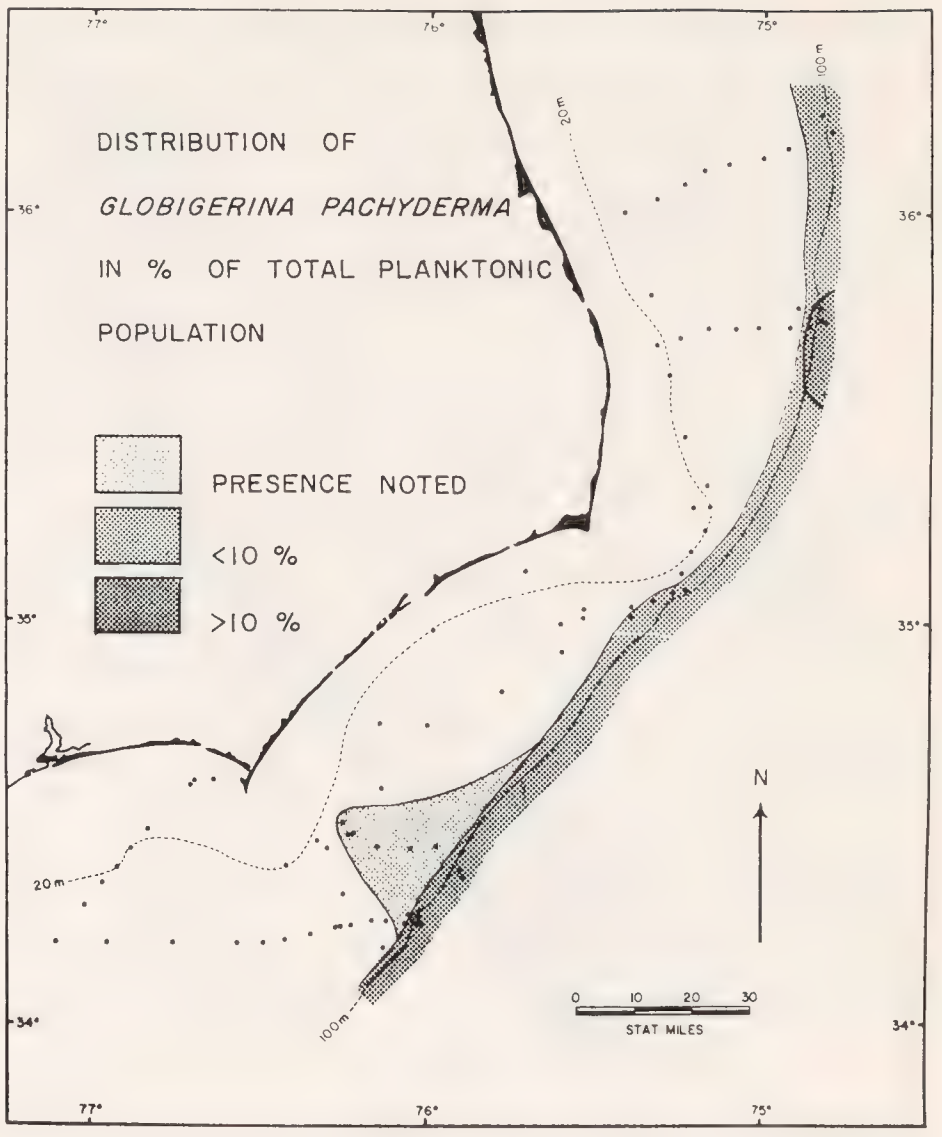


Figure 33

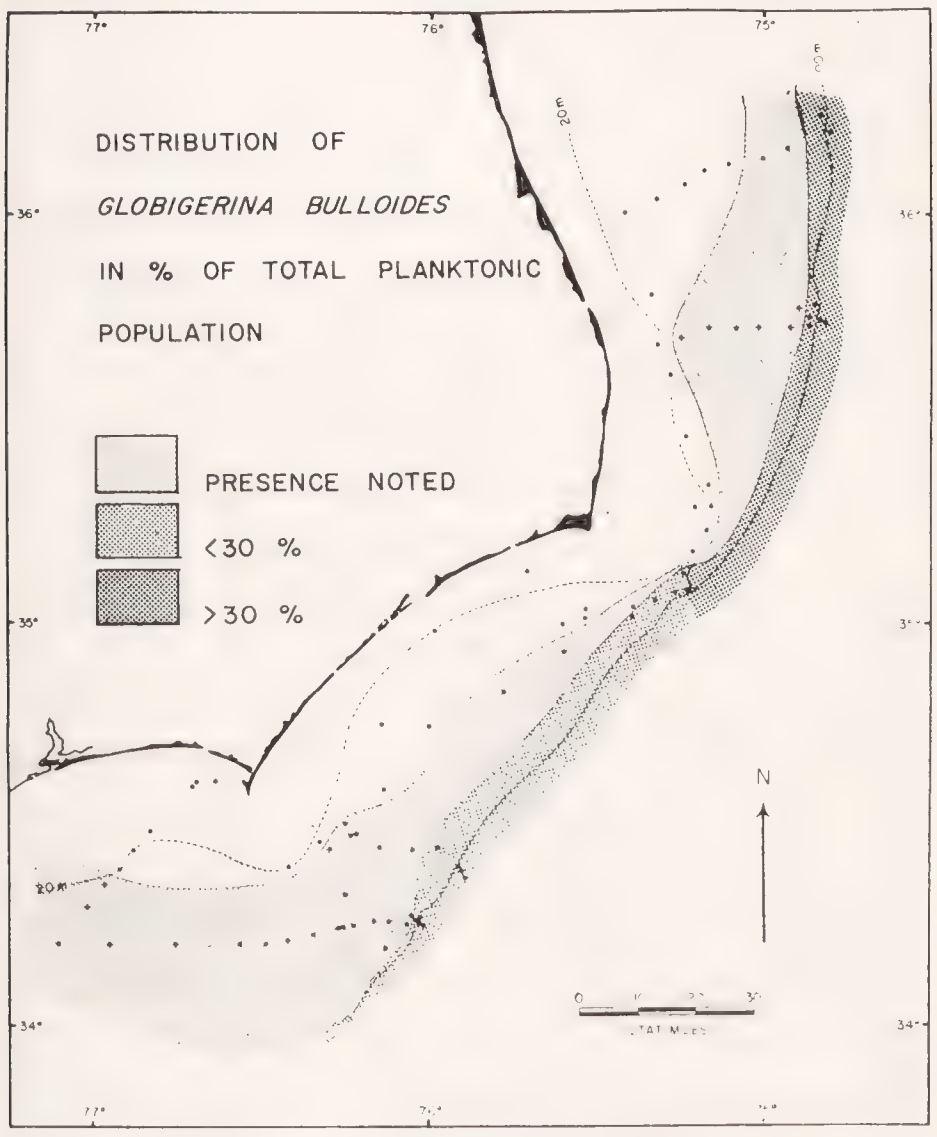


Figure 32

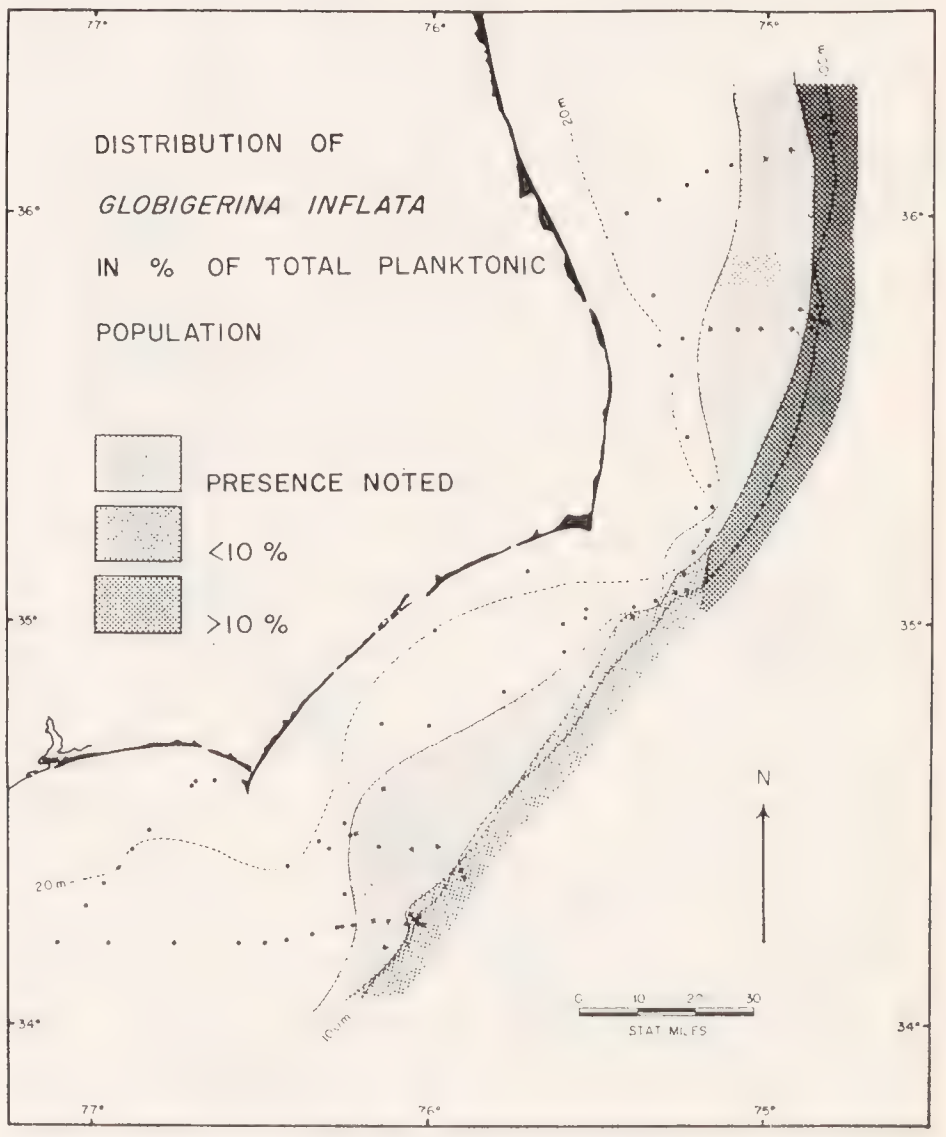


Figure 34

the Georgia continental shelf edge (Pilkey *et al.*, 1966). Occurrences of "larger" foraminifera may corroborate this assumption. *Amphistegina lessonii*, *Textulariella barrettii* and *Textularia pseudotrochus* occur exclusively along the shelf edge with no living representatives. The first two species are part of a fauna which Ludwick and Walton (1957) found associated with dead reef structures along the shelf edge of the northeastern Gulf of Mexico. They concluded that these reefs grew when sealevel was about 60 meters

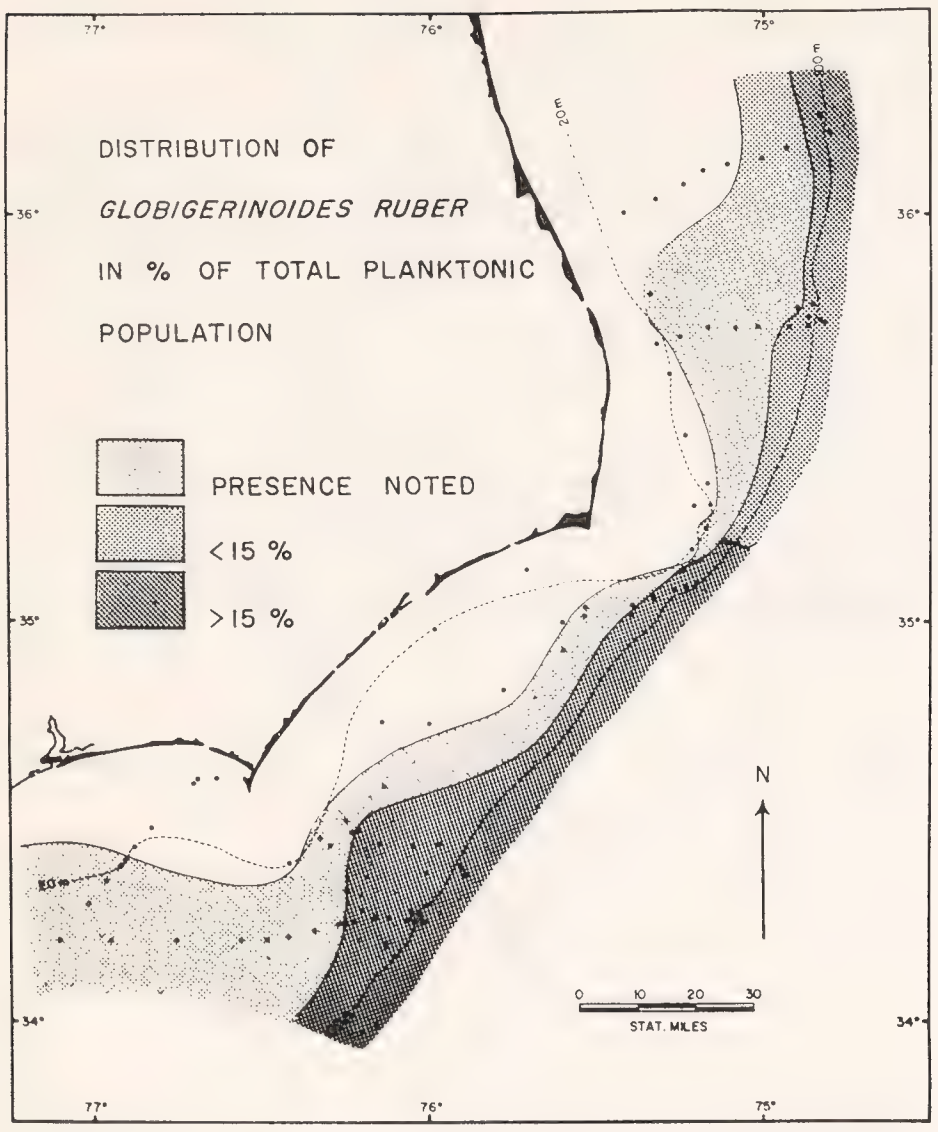


Figure 35

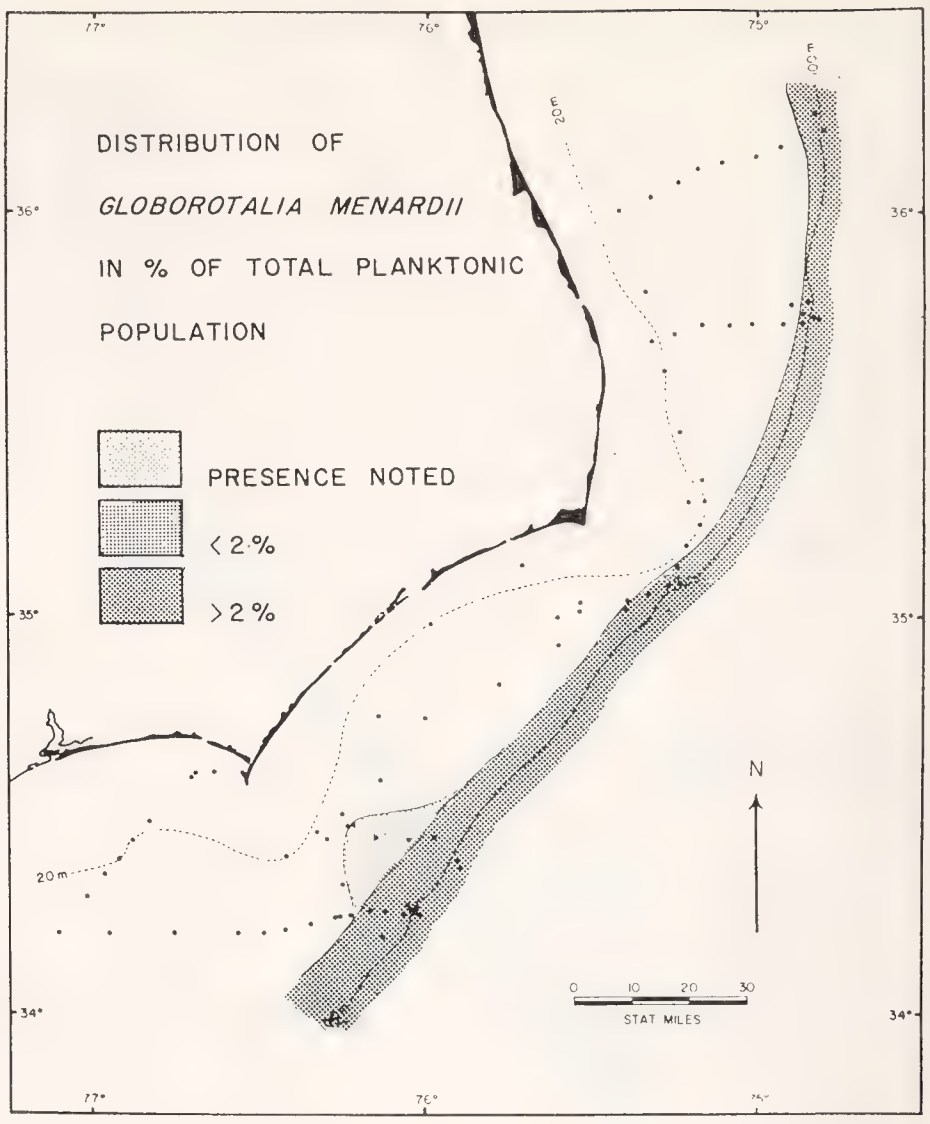


Figure 37

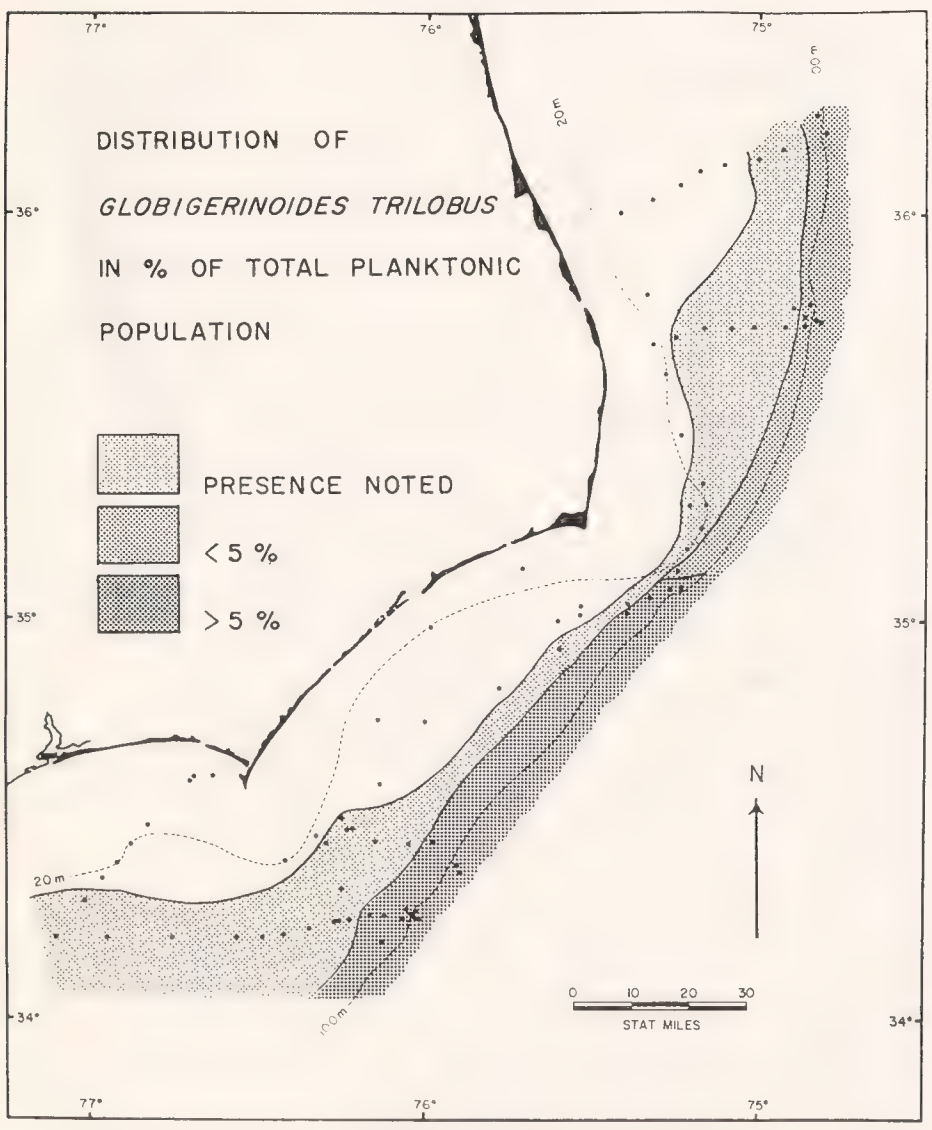


Figure 36

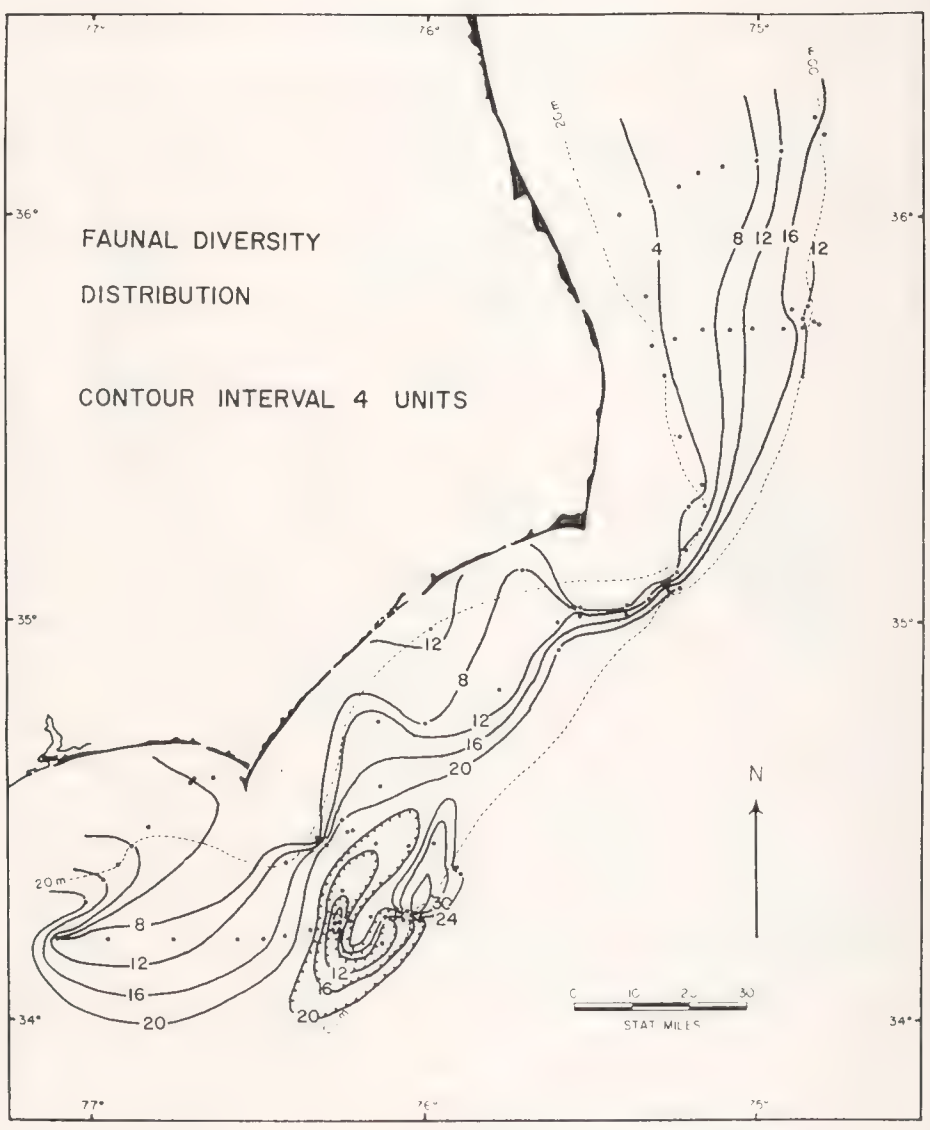


Figure 38

below the present level, probably during the last stage of the Pleistocene glaciation. The dead foraminifera associated with the reef have their living equivalents in the shallow water off the coast of Florida and in the Florida reefs.

## F. Planktonic Foraminifera

The distribution of planktonic foraminiferal tests is very closely correlated with depth. The shallowest specimens appear at depths between 20 and 30 meters. At a

depth of 70 meters abundance increases abruptly, with frequencies of more than 100 specimens per cubic centimeter, at 140 meters an abundance of 1834 specimens per cubic centimeter was reached (Figure 31). The occurrence of the planktonic species in the samples is listed in Table III. A similar increase of the abundance of planktonic foraminifera was observed by Bandy (1956) and by Walton (1964) in the northeastern Gulf of Mexico. This regularity of distribution allows reconstruction of bathymetry of fossil faunas as was already done by Smith (1955) and Hay (1960). Bandy (1956) found that certain species appeared farther inshore than others and concluded that the shallowest occurrence of a species in bottom sediments coincided with the upper limit at which the species occurred in the water column. Studies of living planktonic foraminifera (Phleger, 1951; Bradshaw, 1959; and Bé, 1960), however, indicate that Bandy's conclusion was incorrect. Bradshaw (1959) suggests that the depths at which a species occurs in sediment is a function of its abundance. The most abundant species of the open water will probably be found closest to shore. Planktonic foraminiferal distribution on the North Carolina shelf seems to support Bradshaw's view. *Globigerinoides ruber* and *Globigerina bulloides,* the most abundant planktonic species overall, are also present in samples from shallowest water. Relatively rare species are almost exclusively found only in the deeper samples, generally below 70 meters.

Bé and Hamlin (1967) identify 20 species of planktonic foraminifera in the North Atlantic, of which 17 have been found in the present study. Bé and Hamlin (1967) also recognize four ecologic categories: subarctic, transitional, subtropical and tropical. Species from all of these ecologic categories occur off the North Carolina coast, indicating that this is an area of faunal mixing. The Gulf Stream apparently brings tropical species north, and the southward drift seems to introduce subarctic and transitional species.

*Globigerina bulloides* (figure 32) is the most abundant planktonic species north of Cape Hatteras where it reaches a maximum abundance of 45% and generally constitutes more than 30% of the planktonic fauna. South of Cape Hatteras it is also abundant but no longer the most numerous species. *Globigerina pachyderma* (figure 33) and *Globigerina quinqueloba* are present along the shelf edge, generally below 70 meters, and are about 3 to 4 times as abundant north of Cape Hatteras than to the south. These species belong to the subarctic fauna of Bé and Hamlin (1967).

*Globigerina inflata* (figure 34), the index species for the transitional faunal zone according to Bé and Hamlin (1967), occurs abundantly along the edge of the North Carolina shelf, even though Bé and Hamlin did not report it from the western North Atlantic coast. North of Cape Hatteras it may comprise 19–23% of the planktonic foraminifera, south of Cape Hatteras the highest frequency recorded is 5%. It is mostly confined to depths greater than 70 meters.

Of the species reported by Bé and Hamlin (1967) as indicators for the subtropical fauna, the following have been found in this investigation: *Globigerinoides ruber, Globigerina dutertrei, Globigerinella aequilateralis, Globorotalia truncatulinoides, Pulleniatina obliqueloculata, Orbulina universa, Globigerinita glutinata, Globorotalia hirsuta* and *Hastigerina pelagica.* Of these, *Globigerinoides ruber* (figure 35) reaches frequencies of up to 60% of the planktonic fauna south of Cape Hatteras, making it the most abundant species there. North of Cape Hatteras its frequencies drop to an average of only 12%. Other species of this group follow the same pattern with the exception of *Hastigerina pelagica,* which does not occur north of Cape Hatteras.

All the species of Bé and Hamlin's (1967) tropical fauna are present in this area. *Globigerinoides trilobus* (figure 36), which is regarded as conspecific with *G. sacculifer* by Bé and Hamlin (1967), is the most abundant, having frequencies of about 10% south of Cape Hatteras, and of about 3–4% north of the Cape. It occurs sporadically only and rarely in samples from less than 60 meters depth. The only other species which occurs in appreciable numbers is *Globorotalia menardii* (figure 37) which reaches frequencies of as much as 11% south of Cape Hatteras and a maximum of only 4% north of the Cape. It is very rare in a few samples

from less than 50 meters depth. *Globigerinoides sacculifer, G. conglobatus* and *Candeina nitida* are very rare and occur only along the shelf edge, north and south of Cape Hatteras.

The distribution patterns of these planktonic species make it possible to outline the area of influence of the tropical and subtropical realm (Gulf Stream) and the transitional and subarctic realm. The divide between these two faunal areas is located at the latitude of Cape Hatteras. It appears, however, that regional study is necessary to bring out distribution patterns because faunal overlap and mixing makes it impossible to define faunal boundaries within a small area.

### G. Influence of Sediment upon Foraminiferal Distribution

Phleger (1960) summarizes the available information and concludes that, with the exception of specific cases, for example, attached species, there is no causal relationship between sediment and foraminiferal distribution. Species restricted to certain sediment types in one area, are present on different sediments elsewhere. Their occurrence appears to be governed by coincidence of certain topographic and oceanographic features. Furthermore, although Uchio (1960) found the standing crop of foraminifera in the San Diego area to increase with decreasing sediment particle size, the reverse is generally true on the North Carolina continental shelf. Here the largest standing corp is on the central shelf in fine and medium-grained sand which is the coarsest sediment in the area.

A remarkable coincidence of very-fine sand and very high foraminiferal population occurs about 20 miles southeast of Cape Lookout in what is probably a shallow depression. The presence of much organic matter, bits of eelgrass, fecal pellets, and other buoyant material seems to indicate that foraminifera may have been swept into this area from the surrounding higher ground by current action. Inasmuch as the number of living foraminifera is in no way unusually high, the large number of dead foraminifera, 2101 in sample 1738, can only be explained by current transport.

Of all individual species only three correlate closely with sediment type. These three species, *Placopsilina confusa, Calcituba decorata,* and *Webbinella concava,* have in common the habit of attaching their tests to sand grains or shell fragments. *Placopsilina confusa,* which may be as much as 2 mm long, is especially dependent upon a coarse grained substrate.

## VII. Faunal Diversity

Recognition of environment is dependent upon identification of the diagnostic coenosis, thanatocoenoesis in this study or in the case of fossil occurrences. The composition of a coenosis, however, is likely to change with localities or time. It is therefore desirable to obtain an abstract measure of coenotic characters which are independent of specific composition. Such an abstraction is the diversity of a faunal assemblage, *i.e.,* the numerical relationship between the number of species in any given fauna and the number of specimens of each species. The usefulness of a faunal diversity measure is based on the observation that, under adverse environmental conditions, individuals of only a few of the species in a faunal assemblage comprise a large number of the population, whereas under normal conditions individuals of the dominant species are less abundant and the greater number of ecologic niches allows for an increase of diversity. Since faunal diversity may be influenced by any combination of environmental factors, a diversity index does not identify any specific factor, but may serve as a means of generalized comparison between diverse communities.

Various statistics have been employed to measure faunal diversity, but few foraminiferal faunas have been analyzed in this respect. Walton (1964) employed the number of ranked species whose cumulative percentage comprises 95% of the total population as a measure of faunal diversity. Gibson (1966) summarizes the biological implications of faunal diversity and demonstrates its use with an example from the Mississippi Sound area. The formula employed by him is from Simpson (1949):

$$\frac{N(N-1)}{\sum_{i=1}^{K} n_i(n_i-1)}$$

where: N = total number of specimens in sample
$n_i$ = number of specimens in the $i^{th}$ species
K = number of species

This formula, because of its relative insensitivity to the rare species produces a diversity index that is a measure of dominance within a fauna and thus is dependent upon sample size (Sanders, 1968). Figure 38 shows the distribution of faunal diversity on the North Carolina continental shelf, contoured according to this formula in four unit intervals. The calculated values for each sampling station are presented in table V. The North Carolina shelf apparently supports an unusually diverse fauna in contrast to the values obtained by Gibson (1966) and values computed for upper Miocene faunas from North Carolina discussed by Schnitker (1966, unpublished MS). The highest index obtained in the Mississippi Sound area is 8, and 12 is the highest for the upper Miocene fauna, whereas the North Carolina shelf maximum is 35.6. Values greater than 15 are common on the shelf. These differences may result in part from the use of somewhat smaller samples in the Mississippi Sound study and from the more "normal" marine conditions on the North Carolina shelf as compared to the Mississippi Sound area. The latter is not exposed to open ocean and may also be influenced by the influx of less saline water from the Mississippi River. It is more likely, however, that the high faunal diversity on the North Carolina shelf is caused by the superposition of two different faunas: The Pleistocene relict fauna and the indigenous fauna. It was not possible to analyze separately the influence of either fauna.

Generally, faunal diversity increases with distance from shore, indicating an approach to more stable "normal" marine conditions and also, that the size of the relict fauna is larger in deeper water. The diversity indices on the entire shelf to the north of Cape Hatteras are about four units lower on the average than those of the southern shelf. The lower complexity of the Virginian fauna is probably caused by the different composition of the Virginian Coastal water and the greater fluctuations of temperature and salinity. These fluctuations are greater in shallow nearshore water, giving rise to lower diversity. Diversity values of four and less are roughly restricted to the area of recent near-shore sediments on the northern shelf and off Cape Hatteras. The decrease in diversity at the outer edge of the shelf indicates that here modern sedimentation and an abundant indigenous fauna (*Islandiella subglobosa* and *Bulimina marginata*) mask the diversifying effect of the relict fauna. South of Cape Hatteras diversity values are high, probably because of the stabilizing influence of Gulf Stream water.

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## Plate 1

Figures

1a, b *Ammodiscus catinus* Höglund, × 102
2a, b *Reophax atlantica* (Cushman), × 50
3a, b *Reophax fusiformis* (Williamson), × 81
4, 5 *Reophax scorpiurus* Montfort, × 23 (fig. 4); × 16 (fig. 5)
6a, b, c *Haplophragmoides canariensis* (d'Orbigny), × 68
7a, b *Ammobaculites dilatatus* Cushman and Bronnimann, × 44
8 *Placopsilina confusa* Cushman, × 19
9a, b, c *Spiroplectammina floridana* (Cushman), × 45
10a, b *Textularia candeiana* d'Orbigny, × 47
11a, b *Textularia conica* d'Orbigny, × 83
12a, b *Textularia truncata* Höglund, × 47
13a, b *Textularia pseudotrochus* Cushman, × 33
14a, b *Siphotextularia curta* (Cushman), × 90
15a, b *Siphotextularia rolshauseni* Phleger and Parker, × 52
16a, b, c *Trochammina advena* Cushman, × 117
17a, b, c *Trochammina squamata* Jones and Parker, × 117
18a, b, c *Trochamminula lobata* (Cushman), × 80
19a, b *Eggerella advena* (Cushman), × 123
20a, b *Textulariella barrettii* (Jones and Parker), × 14

PLATE 1
1a
1b
2b
3b
2a
3a
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6a
6b
7b
9c
10b
6c
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17a
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19a
19b
20b
20a

PLATE 1

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## Plate 2

Figures

1a, b *Cyclogyra planorbis* (Schultze), × 99
2a, b, c *Cyclogyra selseyensis* (Heron-Allen and Earland), × 65
3a, b, c *Fischerinella dubia* (d'Orbigny), × 90
4, 5 *Calcituba decorata* (Heron-Allen and Earland), × 96 (fig. 4); × 31 (fig. 5)
6 *Cornuloculina inconstans* (Brady), × 67
7a, b, c *Edentostomina cultrata* (Brady), × 52
8a, b *Nodobacullariella atlantica* Cushman and Hanzawa, × 79
9a, b, c *Wiesnerella auriculata* (Egger), × 96
10a, b *Spiroloculina atlantica* Cushman, × 51
11a, b *Spiroloculina depressa* d'Orbigny, × 70
12a, b, c *Quinqueloculina bicostata* d'Orbigny, × 40
13a, b, c *Quinqueloculina bosciana* d'Orbigny, × 58
14a, b, c *Quinqueloculina compta* Cushman, × 50
15a, b, c *Quinqueloculina jugosa* Cushman, × 54
16a, b, c *Quinqueloculina lamarckiana* d'Orbigny, × 85
17a, b, c *Quinqueloculina poeyana* d'Orbigny, × 108
18a, b, c *Quinqueloculina polygona* d'Orbigny, × 48

PLATE 2
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PLATE 2

*Edentostomina cultrata* (Brady) (Plate 2, Figure 7); *Miliolina cultrata* Brady, 1884, Rept. Voy. *Challenger,* Zool., vol. 9, p. 161, pl. 5, figs. 1, 2.

*Eggerella advena* (Cushman) (Plate 1, Figure 19); *Verneuilina advena* Cushman, 1921, Contr. Canadian Biol., no. 9, p. 141.

*Elphidiella* sp., cf. *E. mexicana* (Kornfeld) (Plate 7, Figure 6); *Elphidium incertum* (Williamson) var. *mexicanum* Kornfeld, 1931, Stanford Univ. Dept. Geol., Contr. 1, p. 89, pl. 16, figs. 1, 2.

*Elphidium advenum* (Cushman) (Plate 7, Figure 2); *Polystomella advena* Cushman, 1922, Carnegie Inst. Washington, Publ. 311, p. 56, pl. 9, figs. 11, 12.

*Elphidium clavatum* Cushman (Plate 7, Figure 5); 1930, U. S. Natl. Mus., Bull. 104, pt. 7, p. 20, pl. 7, fig. 10.

*Elphidium incertum* (Williamson) (Plate 7, Figure 4); *Polystomella umbilicatula* (Walker) var. *incerta* Williamson, 1858, Rec. Foram. Gt. Britain, p. 44, pl. 3, fig. 82a.

*Elphidium subarcticum* Cushman (Plate 7, Figure 3); Cushman Lab. Foram. Res., Spec. Publ. 12, p. 27, pl. 3, figs. 34, 35.

*Eponides antillarum* (d'Orbigny) (Plate 8, Figure 11); *Rotalina antillarum* d'Orbigny, 1839, *in* de la Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminifères, p. 75, vol. 8, pl. 5, figs. 4–6.

*Eponides tumidulus* (Brady) (Plate 9, Figure 1); *Truncatulina tumidula* Brady, 1884, Rept. Voy. *Challenger,* Zool., vol. 9, p. 666, pl. 95, fig. 8.

*Eponides repandus* (Fichtel & Moll) (Plate 9, Figure 2); *Nautilus repandus* Fichtel & Moll, Test. Micr., 1798, p. 35, pl. 3, figs. a–d.

*Fischerinella dubia* (d'Orbigny) (Plate 2, Figure 3); *Rotalina* (*Rotalina*) *dubia* d'Orbigny, 1839, *in* de la Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminifères, p. 78, vol. 8, pl. 2, figs. 29, 30.

*Fissurina lacunata* (Burrows & Holland) (Plate 4, Figure 14); *Lagena lacunata* Burrows & Holland, 1895, *in* Jones, Foram. Crag, p. 205, pl. 7, figs. 12a, b.

*Fissurina lucida* (Williamson) (Plate 4, Figure 15); *Entosolenia marginata* Montagu var. *lucida* Williamson, 1848, Ann. Mag. Nat. Hist., ser. 2, vol. 1, p. 17, pl. 2, fig. 17.

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## Plate 3

Figures

1a, b, c *Quinqueloculina seminula* (Linné), × 94
2a, b *Pyrgo denticulata* (Brady), × 45
3a, b *Pyrgo oblonga* (d'Orbigny), × 77
4a, b *Pyrgo serrata* (Bailey), × 49
5a, b *Pyrgo subsphaerica* (d'Orbigny), × 84
6a, b *Sigmoilina antillarum* (d'Orbigny), × 68
7a, b *Sigmoilina tenuis* (Czjzek), × 91
8a, b, c *Siphonaptera horrida* (Cushman), × 45
9a, b, c *Siphonaptera sabulosa* (Cushman), × 79
10a, b *Triloculina tricarinata* d'Orbigny, × 75
11a, b *Triloculina trigonula* (Lamarck), × 52
12a, b *Miliolinella circularis* (Bornemann), × 60
13a, b *Miliolinella fichteliana* (d'Orbigny), × 58
14a, b, c *Scutuloris* sp., cf. *S. procera* (Göes), × 102
15a, b, c *Articulina sagra* d'Orbigny, × 108
16 *Peneroplis discoideus* Flint, × 20
17a, b *Peneroplis proteus* d'Orbigny, × 47
18a, b *Nodosaria catesbyi* d'Orbigny, × 67
19a, b *Astacolus crepidulus* (Fichtel and Moll), × 66
20a, b *Dentalina communis* (d'Orbigny), × 21

PLATE 3
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PLATE 3

*Fissurina stewartii* (Wright) (Plate 4, Figure 16); *Lagena stewartii* Wright, 1911, Belfast Nat. Field Club, Proc. ser. 2, vol. 6, no. 2, p. 12, pl. 2, fig. 8.

*Florilus atlanticus* (Cushman) (Plate 10, Figure 8); *Nonionella atlantica* Cushman, 1947, Cushman Lab. Foram. Res., Contr., vol. 23, pt. 4, p. 90, pl. 20, figs. 4, 5.

*Florilus auriculus* (Heron-Allen & Earland) (Plate 10, Figure 9); *Nonionella auricula* Heron-Allen & Earland, 1930, Roy. Micr. Soc., Jour., vol. 50, p. 192, pl. 5, figs. 68–70.

*Fursenkiona fusiformis* (Williamson) (Plate 10, Figure 1); *Bulimina pupoides* d'Orbigny var. *fusiformis* Williamson, 1858, Rec. Foram. Gt. Britain, p. 63, pl. 5, figs. 129, 130.

*Fursenkoina punctata* (d'Orbigny) (Plate 10, Figure 2); *Virgulina punctata* d'Orbigny, 1839, *in* de la Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminifères, p. 139, vol. 8, pl. 1, figs. 35, 36.

*Glabratella lauriei* (Heron-Allen & Earland) (Plate 6, Figure 7); *Discorbina lauriei* Heron-Allen & Earland, 1924, Linn. Soc. London, Jour., Zool., vol. 35, p. 633, pl. 36, figs. 50–52, pl. 37, figs. 53–55.

*Globigerina bulloides* d'Orbigny (Plate 7, Figure 13); 1826, Ann. Sci. Nat., vol. 7, p. 277; mod. no. 76.

*Globigerina dutertrei* d'Orbigny (Plate 7, Figure 12); 1839, *in* de la Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminifères, p. 84, vol. 8, pl. 8, fig. 4.

*Globigerina inflata* d'Orbigny (Plate 7, Figure 14); 1839, *in* Barker-Webb & Berthelot, Hist. Nat. Îles Canaries, vol. 2, pt. 2, Foraminifères, p. 134, pl. 2, figs. 7–9.

*Globigerina pachyderma* (Ehrenberg) (Plate 8, Figure 2); *Aristerospira pachyderma* Ehrenberg, 1861, Monats. k. preuss. Akad.

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## Plate 4

Figures

1a, b *Lagena acuticosta* Reuss, × 140
2a, b *Lagena laevis* (Montagu), × 85
3a, b *Lagena striata* (d'Orbigny), × 76
4 *Lagena tenuis* (Bornemann), × 64
5a, b *Lenticulina orbicularis* (d'Orbigny), × 31
6a, b *Marginulina advena* (Cushman), × 29
7a, b *Marginulina bachei* Bailey, × 13.5
8a, b *Marginulina villa* Cushman, × 61
9a, b *Guttulina caribaea* d'Orbigny, × 85
10a, b *Guttulina lactea* (Walker and Jacob), × 98
11a, b *Guttulina pulchella* d'Orbigny, × 59
12a, b, c *Webbinella concava* (Williamson), × 106
13a, b *Oolina melo* d'Orbigny, × 116
14a, b *Fissurina lacunata* (Burrows and Holland), × 124
15a, b *Fissurina lucida* (Williamson), × 112
16a, b *Fissurina stewartii* (Wright), × 182
17a, b *Buliminella elegantissima* (d'Orbigny), × 121
18 *Sphaeroidina bulloides* d'Orbigny, × 147
19a, b *Bolivina alata* (Seguenza), × 40
20a, b *Bolivina albatrossi* Cushman, × 79
21a, b *Bolivina subaenariensis mexicana* Cushman, × 56
22a, b *Bolivina lowmani* Phleger and Parker, × 102
23a, b *Bolivina pseudoplicata* Heron-Allen and Earland, × 92
24a, b *Bolivina spathulata* (Williamson), × 85
25a, b *Bolivina lanceolata* Parker, × 74
26a, b *Rectobolivina advena* (Cushman), × 67

PLATE 4
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PLATE 4

Wiss., Berlin, pp. 276, 277, 303; 1872, (1873), Abhandl. k. Akad. Wiss., Berlin, pl. 1, fig. 4.

*Globigerina quinqueloba* Natland (Plate 8, Figure 1); 1938, Bull. Scripps Inst. Ocean., Techn. Ser., vol. 4, no. 5, p. 149, pl. 6, fig. 7.

*Globigerinita glutinata* (Egger) (Plate 8, Figure 8); *Globigerina glutinata* Egger, 1893, Abhandl. k. Akad. Wiss., München, Cl. 2, vol. 18, p. 371, pl. 13, figs. 19–21.

*Globigerinoides conglobatus* (Brady) (Plate 8, Figure 3); *Globigerina conglobata* Brady, 1884, Rept. Voy. *Challenger,* Zool., vol. 9, p. 603, pl. 80, fig. 5.

*Globigerinoides ruber* (d'Orbigny) (Plate 8, Figure 5); *Globigerina rubra* d'Orbigny, 1839, *in* de la Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminifères, p. 82, vol. 8, pl. 4, figs. 12–14.

*Globigerinoides sacculifer* (Brady) (Plate 8, Figure 4);*Globigerina sacculifera* Brady, 1877, Geol. Mag., vol. 4, p. 535; 1884, Rept. Voy. *Challenger,* Zool., vol. 9, p. 604, pl. 80, figs. 11–17; pl. 82, fig. 4.

*Globigerinoides trilobus* (Reuss) (Plate 8, Figure 7); *Globigerina triloba* Reuss, 1850, Denkschr. k. Akad. Wiss., Wien, vol. 1, p. 374, pl. 47, fig. 11.

*Globobulimina auriculata* (Bailey) (Plate 5, Figure 6); *Bulimina auriculata* Bailey, 1851, Smithsonian Contr., vol. 2, p. 12, pl., figs. 25–27.

*Globorotalia hirsuta* (d'Orbigny) (Plate 7, Figure 7); *Rotalina hirsuta* d'Orbigny, 1839, *in* Barker-Webb & Berthelot, Hist. Nat. Îles Canaries, vol. 2, pt. 2, Foraminifères, p. 131, pl. 1, figs. 37–39.

*Globorotalia menardii* (d'Orbigny) (Plate 7, Figure 10); *Rotalia menardii* d'Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 273, mod. no. 10.

*Globorotalia truncatulinoides* (d'Orbigny) (Plate 7, Figure 11); *Rotalina truncatulinoides* d'Orbigny, 1839, *in* Barker-Webb & Berthelot, Hist. Nat. Îles Canaries, vol. 2, pt. 2, Foraminifères, p. 132, pl. 2, figs. 25–27.

*Guttulina caribaea* d'Orbigny (Plate 4, Figure 9); 1839, *in* de la Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminifères, p. 135, vol. 8, pl. 2, figs. 7, 8.

*Guttulina lactea* (Walker & Jacob) (Plate 4, Figure 10); *Serpula lactea* Walker & Jacob, 1798, Adam's Essays, ed. 2, p. 634, pl. 24, fig. 4.

*Guttulina pulchella* d'Orbigny (Plate 4, Figure 11); 1839, *in* de la Sagra, Hist.

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## Plate 5

Figures

1a, b, c *Islandiella subglobosa* (Brady), × 121
2a, b, c *Cassidulinoides bradyi* (Norman), × 103
3a, b *Stilostomella antillea* (Cushman), × 55
4a, b *Bulimina aculeata* d'Orbigny, × 85
5a, b *Bulimina marginata* d'Orbigny, × 104
6a, b *Globobulimina auriculata* (Bailey), × 67
7a, b *Stainforthia complanata* (Egger), × 77
8a, b *Reussella atlantica* Cushman, × 94
9a, b *Bulimina alazanensis* Cushman, × 121
10a, b *Uvigerina auberiana* d'Orbigny, × 108
11a, b *Uvigerina peregrina* Cushman, × 84
12a, b *Sagrina pulchella* d'Orbigny, × 100
13a, b *Trifarina angulosa* (Williamson), × 84
14a, b *Trifarina bradyi* Cushman, × 81
15a, b, c *Buccella hannai* (Phleger and Parker), × 102
16a, b, c *Neoconorbina terquemi* (Rzehak), × 56
17a, b, c *Discorbinella bertheloti* (d'Orbigny), × 58
18a, b, c *Rosalina floridensis* (Cushman), × 101
19a, b, c *Rosalina floridana* (Cushman), × 105

PLATE 5
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PLATE 5

Phys. Pol. Nat. Cuba, Foraminifères, p. 134, vol. 8, pl. 2, figs. 4–6.

*Gyroidina orbicularis* d'Orbigny (Plate 9, Figure 9); 1826, Ann. Sci. Nat., ser. 1, vol. 7, p. 278.

*Hanzawaia concentrica* (Cushman) (Plate 10, Figure 13); *Cibicides concentrica* Cushman, 1918, U.S. Geol. Survey, Bull. 676, p. 64, pl. 21, fig. 3; 1931.

*Haplophragmoides canariensis* (d'Orbigny) (Plate 1, Figure 6); *Nonionina canariensis* d'Orbigny, 1839, *in* Barker-Webb & Berthelot, Hist. Nat. Îles Canaries, vol. 2, pt. 2, Foraminifères, p. 128, pl. 2, figs. 33, 34.

*Hastigerina aequilateralis* (Brady) (Plate 7, Figure 8); *Globigerina aequilateralis* Brady, 1884, Rept. Voy. *Challenger,* Zool. vol. 9, p. 605, pl. 80, figs. 18–21.

*Hastigerina pelagica* (d'Orbigny) (Plate 7, Figure 9); *Nonionina pelagica* d'Orbigny, 1839, Voy. Amér. Mérid., Foraminifères, vol. 5, pt. 5, p. 27, pl. 3, figs. 13, 14.

*Höglundina elegans* (d'Orbigny) (Plate 10, Figure 15); *Rotalia* (*Turbulina*) *elegans* d'Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 276.

*Islandiella subglobosa* (Brady) (Plate 5, Figure 1); *Cassidulina subglobosa* Brady, 1881, Quart. Jour. Micr. Sci., vol. 21, p. 60; Brady, 1884, Rept. Voy. *Challenger,* Zool., vol. 9, p. 430, pl. 54, figs. 17a–c.

*Lagena acuticosta* Reuss (Plate 4, Figure 1); 1861, Sitz. Akad. Wiss., Wien, vol. 44, pt. 1, p. 305, pl. 1, fig. 4.

*Lagena laevis* (Montagu) (Plate 4, Figure 2); *Vermiculum laeve* Montagu, 1803, Test. Brit. p. 524. *Lagena laevis* (Montagu). Williamson, 1848, Ann. Mag. Nat. Hist., ser. 2, vol. 1, p. 12, pl. 1, figs. 1, 2.

*Lagena striata* (d'Orbigny) (Plate 4, Figure 3); *Oolina striata* d'Orbigny, 1839, Voy. Amér. Mérid., Foraminifères, p. 21, pl. 5, fig. 12.

*Lagena tenuis* (Bornemann) (Plate 4, Figure 4); *Ovulina tenuis* Bornemann, 1855, Deutsche geol. Ges., Zeitschr., vol. 7, pt. 2, p. 317, pl. 12, fig. 3.

*Lenticulina orbicularis* (d'Orbigny) (Plate 4, Figure 5); *Robulina orbicularis* d'Orbigny, 1826, Tabl. Meth., p. 288, figs. 8, 9.

*Marginulina advena* (Cushman) (Plate 4, Figure 6); *Vaginulina advena* Cushman, 1923, U. S. Natl. Mus., Bull. 104, pt. 4, p. 134, pl. 39, figs. 1–4.

*Marginulina bachei* Bailey (Plate 4, Figure 7); 1851, Smithsonian Contr., vol. 2, p. 10, figs. 2–6.

*Marginulina villa* Cushman (Plate 4, Figure 8); 1947, Cushman Lab. Foram. Res., Contr., vol. 23, pt. 4, p. 89, pl. 19, figs. 7, 8.

*Melonis pompilioides* (Fichtel & Moll) (Plate 10, Figure 14); *Nautilus pompilioides* Fichtel & Moll, 1798, Test. Micr., p. 31, pl. 2, figs. a–c.

*Miliolinella circularis* (Bornemann) (Plate 3, Figure 12); *Triloculina circularis* Bornemann, 1855, Zeitschr. deutsch. geol. Ges., vol. 7, pt. 2, p. 349, pl. 19, fig. 4.

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## Plate 6

Figures

1a, b, c *Rosalina globularis* d'Orbigny, × 103
2a, b, c *Rosalina rugosa* d'Orbigny, × 58
3a, b, c *Stetsonia minuta* Parker, × 89
4a, b, c *Cymbaloporetta atlantica* (Cushman), × 100
5a, b, c *Cancris sagra* (d'Orbigny), × 103
6a, b, c *Valvulineria laevigata* Phleger and Parker, × 119
7a, b, c *Glabratella lauriei* (Heron-Allen and Earland), × 165
8a, b, c *Siphonina pulchra* Cushman, × 59
9a, b, c *Asterigerina carinata* d'Orbigny, × 54
10a, b, c *Asterigerinata pulchella* (Parker), × 110
11a, b, c *Conicospirillina atlantica* Cushman, × 83
12a, b, c *Patellina corrugata* Williamson, × 114

PLATE 6

PLATE 6

*Miliolinella fichteliana* (d'Orbigny) (Plate 1, Figure 13); *Triloculina fichteliana* d'Orbigny, 1839, *in* de la Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminifères, p. 171, vol. 8, pl. 9, figs. 8–10.

*Mississippina concentrica* (Parker & Jones) (Plate 10, Figure 16); *Pulvinulina concentrica* Parker & Jones, *in* Brady, 1864, Trans. Linn. Soc. Zool., vol. 24, p. 470, pl. 48, fig. 14.

*Neoconorbina terquemi* (Rzehak) (Plate 5, Figure 16); *Discorbina terquemi* Rzehak, 1888, Geol. Reichsanst., Verh. Wien, no. 11, p. 228.

*Nodobacculariella atlantica* Cushman & Hanzawa (Plate 2, Figure 8); 1937, Cushman Lab. Foram. Res., Contr., vol. 13, pt. 2, p. 42, pl. 5, figs. 7, 8.

*Nodosaria catesbyi* d'Orbigny (Plate 3, Figure 18); 1839, *in* de la Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminifères, p. 16, vol. 8, pl. 1, figs. 8–10.

*Nonion grateloupi* (d'Orbigny) (Plate 10, Figure 6); *Nonionina grateloupi* d'Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 294; 1839, *in* de la Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminifères, p. 46, vol. 8, pl. 6, figs. 6, 7.

*Nonionella turgida* (Williamson) (Plate 10, Figure 10); *Rotalina turgida* Williamson, 1958, Rec. Foram. Gt. Britain, p. 50, pl. 4, figs. 95–97.

*Oolina melo* d'Orbigny (Plate 4, Figure 13); 1839, Voy. Amér. Mérid., Foraminifères, vol. 5, pt. 5, p. 20, pl. 5, fig. 9.

*Orbulina universa* d'Orbigny (Plate 8, Figure 9); 1839, *in* de la Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminifères, p. 3, vol. 8, pl. 1, fig. 1.

*Patellina corrugata* Williamson (Plate 6, Figure 12); 1858, Rec. Foram. Gt. Britain, p. 46, pl. 3, figs. 86–89.

*Peneroplis discoideus* Flint (Plate 3, Figure 16); *Peneroplis pertusus* (Forskål) var. *discoideus* Flint, 1897, (1899), U. S. Natl. Mus., Rept., p. 304, pl. 49, figs. 1, 2.

*Peneroplis proteus* d'Orbigny (Plate 3, Figure 17); 1839, *in* de la Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminifères, p. 66, vol. 8, p. 8, figs. 4–7.

*Placopsilina confusa* Cushman (Plate 1, Figure 8); 1920, U. S. Natl. Mus., Bull. 104, p. 71, pl. 14, fig. 6.

*Planorbulina mediterranensis* d'Orbigny (Plate 9, Figure 11); 1826, Ann. Sci. Nat., vol. 7, p. 280, no. 2, pl. 14, figs. 1–3.

*Planulina ariminensis* d'Orbigny (Plate 9, Figure 4); 1826, Ann. Sci. Nat., vol. 7, p. 280, pl. 14, figs. 1–3.

*Planulina exorna* Phleger & Parker (Plate 9, Figure 6); 1951, Geol. Soc. America, Mem. 46, pt. 2, p. 32, pl. 18, figs. 5–8.

*Planulina ornata* (d'Orbigny) (Plate 9, Figure 5); *Truncatulina ornata* d'Orbigny, 1839, Voy. Amér. Mérid., vol. 5, pt. 5, Foraminifères, p. 40, pl. 6, figs. 7–9.

*Pullenia quinqueloba* (Reuss) (Plate 10, Figure 11); *Nonionina quinqueloba* Reuss, 1851, Zeitschr. deutsch. Geol. Ges., vol. 3, p. 71, pl. 5, fig. 1.

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## Plate 7

Figures

1a, b, c *Ammonia beccarii* (Linné), × 40
2a, b *Elphidium advenum* (Cushman), × 70
3a, b *Elphidium subarcticum* Cushman, × 60
4a, b *Elphidium incertum* (Williamson), × 108
5a, b *Elphidium clavatum* (Cushman), × 67
6a, b *Elphidiella mexicanum* (Kornfeld), × 61
7a, b, c *Globorotalia hirsuta* (d'Orbigny), × 98
8a, b *Hastigerina aequilateralis* (Brady), × 40
9a, b *Hastigerina pelagica* (d'Orbigny), × 70
10a, b, c *Globorotalia menardii* (d'Orbigny), × 35
11a, b, c *Globorotalia truncatulinoides* (d'Orbigny), × 50
12a, b, c *Globigerina dutertrei* d'Orbigny, × 58
13a, b, c *Globigerina bulloides* d'Orbigny, × 77
14a, b, c *Globigerina inflata* d'Orbigny, × 54

PLATE 7

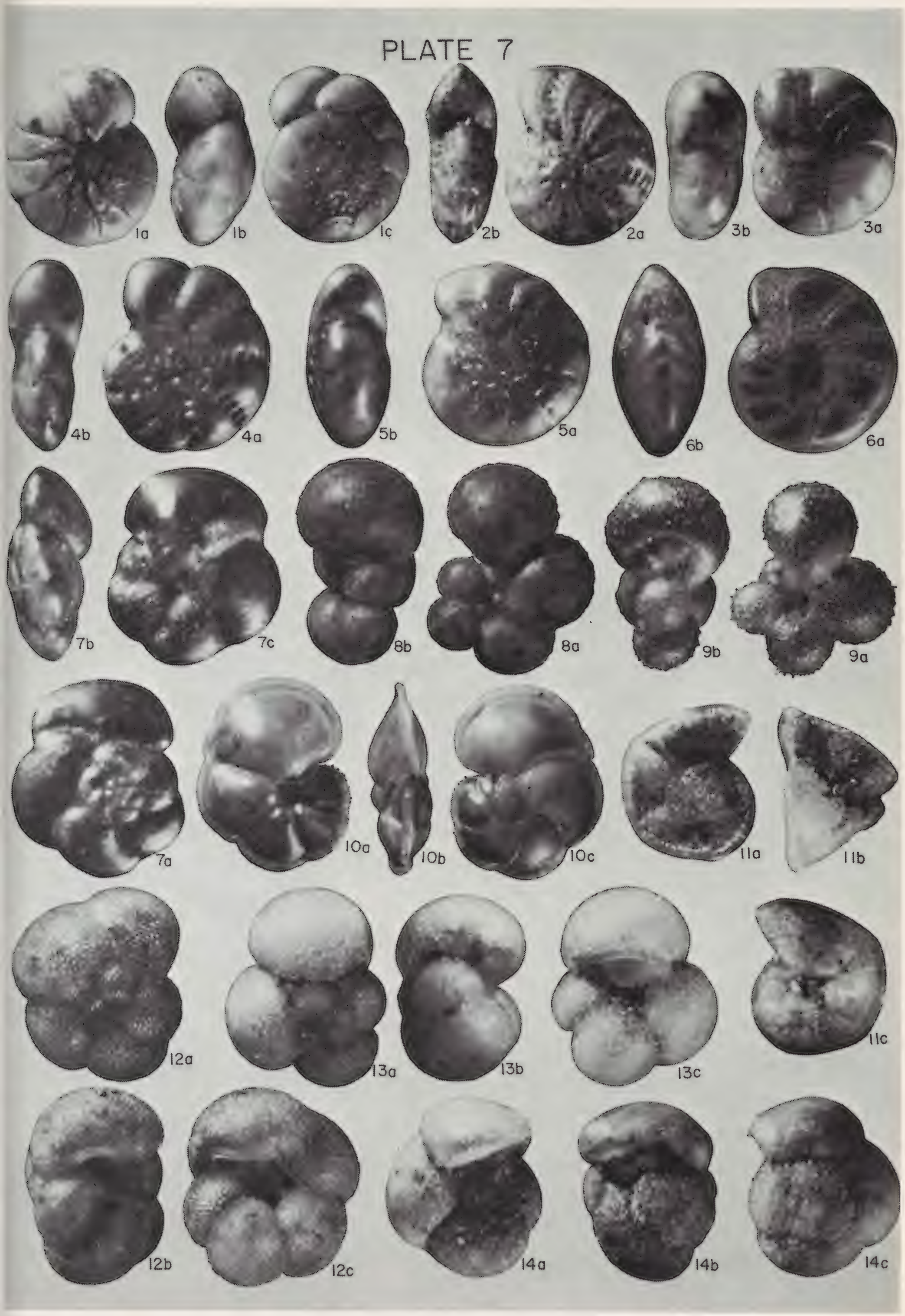


PLATE 7

*Pulleniatina obliqueloculata* (Parker & Jones) (Plate 8, Figure 6); *Pullenia sphaeroides* (d'Orbigny) var. *Obliqueloculata* Parker & Jones, 1865, Philos. Trans. Roy. Soc. London, vol. 155, pp. 365, 368, pl. 19, fig. 4.

*Pyrgo denticulata* (Brady) (Plate 3, Figure 2); *Biloculina ringens* (Lamarck) var. *denticulata* Brady, 1884, Rept. Voy. *Challenger,* Zool., vol. 9, p. 143, pl. 3, figs. 4, 5.

*Pyrgo oblonga* (d'Orbigny) (Plate 3, Figure 3); *Biloculina oblonga* d'Orbigny, 1839, *in* de la Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminifères, p. 163, vol. 8, pl. 8, figs. 21–23.

*Pyrgo serrata* (Bailey) (Plate 3, Figure 4); *Biloculina serrata* Bailey, 1861, Boston Jour. Nat. Hist., vol. 7, no. 3, p. 350, pl. 8, fig. E.

*Pyrgo subsphaerica* (d'Orbigny) (Plate 3, Figure 5); *Biloculina subsphaerica* d'Orbigny, 1839; *in* de la Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminifères, p. 168, vol. 8, pl. 8, figs. 25–27.

*Quinqueloculina bicostata* d'Orbigny (Plate 2, Figure 12); 1839, *in* de la Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminifères, p. 195, v. 8, pl. 12, figs. 8–10.

*Quinqueloculina bosciana* d'Orbigny (Plate 2, Figure 13); 1839, *in* de la Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminifères, p. 191, v. 8, pl. 11, figs. 22–24.

*Quinqueloculina compta* Cushman (Plate 2, Figure 14); 1947, Cushman Lab. Foram. Res., Contr., vol. 23, pt. 4, p. 87, pl. 19, fig. 2.

*Quinqueloculina jugosa* Cushman (Plate 2, Figure 15); *Quinqueloculina seminulum* (Linné) var. *jugosa* Cushman, 1944, Cushman Lab. Foram. Res., Spec. Publ. 12, p. 13, pl. 2, fig. 15.

*Quinqueloculina lamarckiana* d'Orbigny (Plate 2, Figure 16); 1839, *in* de la Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminifères, p. 189, vol. 8, pl. 11, figs. 14, 15.

*Quinqueloculina poeyana* d'Orbigny (Plate 2, Figure 17); 1839, *in* de la Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminifères, p. 191, vol. 8, pl. 11, figs. 25–27.

*Quinqueloculina polygona* d'Orbigny (Plate 2, Figure 18); 1839, *in* de la Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminifères, p. 198, vol. 8, pl. 12, figs. 21–23.

*Quinqueloculina seminula* (Linné) (Plate 3, Figure 1); *Serpula seminulum* Linné, 1758, Syst. Nat., 10th ed., vol. 1, p. 786, pl. 2, fig. 1a–c.

*Rectobolivina advena* (Cushman) (Plate 4, Figure 26); *Siphogenerina advena* Cushman, 1922, Carnegie Inst. Washington, Publ. 311, p. 35, pl. 5, fig. 2.

*Reophax atlantica* (Cushman) (Plate 1, Figure 2); *Proteonina atlantica* Cushman, 1944, Cushman Lab. Foram. Res., Spec. Publ. 12, p. 5, pl. 1, fig. 4.

*Reophax fusiformis* (Williamson) (Plate 1, Figure 3); *Proteonina fusiformis* Williamson, 1858, Rec. Foram. Gt. Britain, p. 1, pl. 1, fig. 1.

*Reophax scorpiurus* Montfort (Plate 1, Figures 4, 5); 1808, Conch. Syst., vol. 1, p. 330.

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## Plate 8

Figures

1a, b, c *Globigerina quinqueloba* Natland, × 130
2a, b, c *Globigerina pachyderma* (Ehrenberg), × 69
3a, b, c *Globigerinoides conglobatus* (Brady), × 46
4a, b, c *Globigerinoides sacculifer* (Brady), × 32
5a, b, c *Globigerinoides ruber* (d'Orbigny), × 48
6a, b *Pulleniatina obliqueloculata* (Parker and Jones), × 50
7a, b, c *Globigerinoides trilobus* (Reuss), × 33
8a, b, c *Globigerinita glutinata* (Egger), × 102
9 *Orbulina universa* d'Orbigny, × 53
10a, b *Candeina nitida* d'Orbigny, × 60
11a, b, c *Eponides antillarum* (d'Orbigny), × 58

PLATE 8

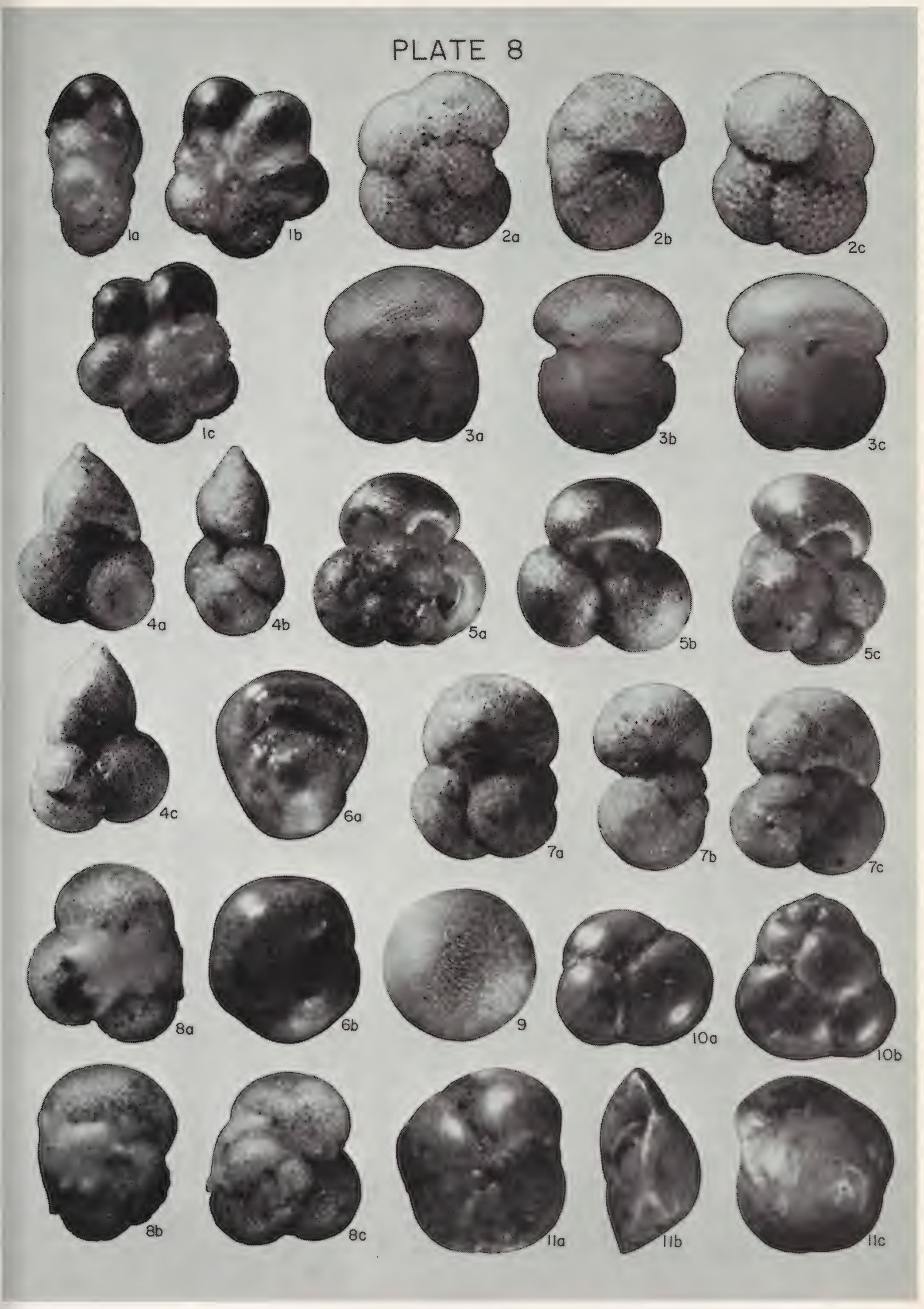


PLATE 8

*Reussella atlantica* Cushman (Plate 5, Figure 8); *Reussella spinulosa* (Reuss) var. *atlantica* Cushman, 1947, Cushman Lab. Foram. Res., Contr., vol. 23, pt. 4, p. 91, pl. 20, figs. 6, 7.

*Robertinoides normani* (Goës) (Plate 10, Figure 17); *Bulmina normani* Goës, 1894, K. Sv. Vet. Akad. Handl., vol. 25, no. 9, p. 47, pl. 9, figs. 437, 438.

*Rosalina floridana* (Cushman) (Plate 5, Figure 19); *Discorbis floridanus* Cushman, 1922, Carnegie Inst. Washington, Publ. 311, p. 39, pl. 5, figs. 11, 12.

*Rosalina floridensis* (Cushman) (Plate 5, Figure 18); *Discorbis floridensis* Cushman, 1931, U. S. Natl. Mus., Bull. 104, pt. 8, p. 17, pl. 3, figs. 3–5.

*Rosalina globularis* d'Orbigny (Plate 6, Figure 1); 1826, Ann. Sci. Nat., vol. 7, p. 271, pl. 13, figs. 1, 2.

*Rosalina rugosa* d'Orbigny (Plate 6, Figure 2); 1839, Voy. Amér. Mérid., Foraminifères, vol. 5, pt. 5, p. 42, pl. 2, figs. 12–14.

*Sagrina pulchella* d'Orbigny (Plate 5, Figure 12); 1839, *in* de la Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminifères, p. 150, pl. 1, figs. 23, 24.

*Scutuloris* sp., cf. *S. procera* (Goës) (Plate 3, Figure 14); *Miliolina procera* Goës, 1896, Harvard Mus. Comp. Zool., Bull. 29, p. 82, pl. 7, figs. 7–9.

*Sigmoilina antillarum* (d'Orbigny) (Plate 3, Figure 6); *Spiroloculina antillarum* d'Orbigny, 1839, *in* de la Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminifères, p. 166, vol. 8, pl. 9, figs. 3, 4.

*Sigmoilina tenuis* (Czjzek) (Plate 3, Figure 7); *Quinqueloculina tenuis* Czjzek, 1848, Naturw. Abh., Wien, vol. 2, p. 149, pl. 13, figs. 31–34.

*Siphonaptera horrida* (Cushman) (Plate 3, Figure 8); *Quinqueloculina horrida* Cushman, 1947, Cushman Lab. Foram. Res., Contr., vol. 23, p. 88, pl. 19, fig. 1.

*Siphonaptera sabulosa* (Cushman) (Plate 3, Figure 9); *Quinqueloculina sabulosa* Cushman, 1947, Cushman Lab. Foram. Res., Contr., vol. 23, pt. 4, p. 87, pl. 18, fig. 22.

*Siphonina pulchra* Cushman (Plate 6, Figure 8); 1910, Carnegie Inst. Washington, Publ. 291, p. 42, pl. 14, fig. 7.

*Siphotextularia curta* (Cushman) (Plate 1, Figure 14); *Textularia flintii* Cushman var. *curta* Cushman, 1922, U. S. Natl. Mus., Bull. 104, pt. 3, p. 14, pl. 2, figs. 2, 3.

*Siphotextularia rolshauseni* Phleger & Parker (Plate 1, Figure 15); 1951, Geol. Soc. America, Mem. 46, pt. 2, p. 4, pl. 1, figs. 23, 24a, b.

*Sphaeroidina bulloides* d'Orbigny (Plate 4, Figure 18); 1826, Ann. Sci. Nat., vol. 7, p. 267.

*Spiroloculina atlantica* Cushman (Plate 2, Figure 10); 1947, Cushman Lab. Foram. Res., Contr., vol. 23, p. 88, pl. 19, figs. 3–5.

*Spiroloculina depressa* d'Orbigny (Plate 2, Figure 11); 1826, Ann. Sci. Nat., vol. 7, p. 298.

*Spiroplectammina floridana* (Cushman) (Plate 1, Figure 9); *Textularia floridana*

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## Plate 9

Figures

1a, b, c *Eponides tumidulus* (Brady), × 144

2a, b, c *Eponides repandus* (Fichtel and Moll), × 48

3a, b, c *Amphistegina lessonii* d'Orbigny, × 36

4a, b, c *Planulina ariminensis* d'Orbigny, × 71

5a, b, c *Planulina ornata* (d'Orbigny), × 66

6a, b, c *Planulina exorna* Phleger and Parker, × 53

7a, b, c *Cibicides pseudoungerianus* (Cushman), × 58

8 *Dyocibicides biserialis* Cushman and Valentine, × 36

9a, b, c *Gyroidina orbicularis* d'Orbigny, × 100

10a, b, c *Caribeanella polystoma* Bermudez, × 95

11a, b, c *Planorbulina mediterranensis* d'Orbigny, × 39

PLATE 9

PLATE 9

Cushman, 1922, Carnegie Inst. Washington, Publ. 311, v. 17, p. 24, pl. 1, fig. 7.

*Stainforthia complanata* (Egger) (Plate 5, Figure 7); *Virgulina schreibersiana* Czjzek var. *complanata* Egger, 1893, Abhandl. k. bay. Akad. Wiss. München, vol. 18, pt. 2, p. 292, pl. 8, figs. 91, 92.

*Stetsonia minuta* Parker (Plate 6, Figure 3); 1954, Harvard Mus. Comp. Zool., Bull. 111, no. 10, p. 534, pl. 10, figs. 27–29.

*Stilostomella antillea* (Cushman) (Plate 5, Figure 3); *Nodosaria antillea* Cushman, 1923, U. S. Natl. Mus., Bull. 104, pt. 4, p. 91, pl. 14, fig. 9.

*Textularia candeiana* d'Orbigny (Plate 1, Figure 10); 1839, *in* de la Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminifères, p. 143, pl. 1, figs. 19, 20.

*Textularia conica* d'Orbigny (Plate 1, Figure 11); 1839, *in* de la Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminifères, p. 143, pl. 1, figs. 25–27.

*Textularia pseudotrochus* Cushman (Plate 1, Figure 13); 1922, U. S. Natl. Mus., Bull. 104, p. 21, pl. 5, figs. 1–3.

*Textularia truncata* Höglund (Plate 1, Figure 12); 1947, Zool. Bidrag Uppsala, Bd. 26, p. 175, pl. 12, figs. 8–9, p. 166, text figs. 147–149.

*Textulariella barrettii* (Jones & Parker) (Plate 1, Figure 20); *Textularia barrettii* Jones & Parker, 1876, Ann. Soc. Mal. Belg., vol. 11, p. 99, text fig.

*Trifarina angulosa* (Williamson) (Plate 5, Figure 13); *Uvigerina angulosa* Williamson, 1858, Rec. Foram. Gt. Britain, p. 67, pl. 5, fig. 140.

*Trifarina bradyi* Cushman (Plate 5, Figure 14); 1923, U. S. Natl. Mus., Bull. 104, pt. 4, p. 99, pl. 22, figs. 3–9.

*Triloculina tricarinata* d'Orbigny (Plate 3, Figure 10); 1826, Ann. Sci. Nat., vol. 7, p. 299.

*Triloculina trigonula* (Lamarck) (Plate 3, Figure 11); *Miliolites trigonula* Lamarck, 1804, Paris Mus. Natl. Hist. Nat., Ann., vol. 5, p. 351, vol. 9, pl. 17, fig. 4.

*Trochammina advena* Cushman (Plate 1, Figure 16); 1922, Carnegie Inst. Washington, Publ. 311, p. 20, pl. 1, figs. 2–4.

*Trochammina squamata* Jones & Parker (Plate 1, Figure 17); 1860, Quart. Jour. Geol. Soc., vol. 16, p. 304.

*Trochamminula lobata* (Cushman) (Plate 1, Figure 18); *Trochammina lobata* Cushman, 1944, Cushman Lab. Foram. Res., Spec. Publ. 12, p. 18, pl. 2, fig. 10.

*Uvigerina auberiana* d'Orbigny (Plate 5, Figure 10); 1839, *in* de la Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminifères, p. 106, pl. 2, figs. 23, 24.

*Uvigerina peregrina* Cushman (Plate 5, Figure 11); 1923, U. S. Natl. Mus., Bull. 104, pt. 4, p. 166, pl. 42, figs. 7–10.

*Valvulineria laevigata* Phleger & Parker (Plate 6, Figure 6); 1951, Geol. Soc.

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## Plate 10

Figures

1a, b *Fursenkoina fusiformis* (Williamson), × 107
2a, b *Fursenkoina punctata* d'Orbigny, × 75
3a, b *Chilostomella oolina* Schwager, × 78
4a, b *Cassidulina neocarinata* Thalmann, × 98
5a, b *Cassidulina laevigata* d'Orbigny, × 99
6a, b *Nonion grateloupi* (d'Orbigny), × 92
7a, b *Astrononion stellatum* Cushman and Edwards, × 83
8a, b, c *Florilus atlanticus* (Cushman), × 55
9a, b, c *Florilus auriculus* (Heron-Allen and Earland), × 94
10a, b, c *Nonionella turgida* (Williamson), × 87
11a, b *Pullenia quinqueloba* (Reuss), × 78
12a, b, c *Cibicides bradyi* (Trauth), × 102
13a, b, c *Hanzawaia concentrica* (Cushman), × 56
14a, b *Melonis pompilioides* (Fichtel and Moll), × 76
15a, b, c *Höglundina elegans* (d'Orbigny), × 60
16a, b, c *Mississippina concentrica* (Parker and Jones), × 62
17a, b *Robertinoides normani* (Goës), × 116

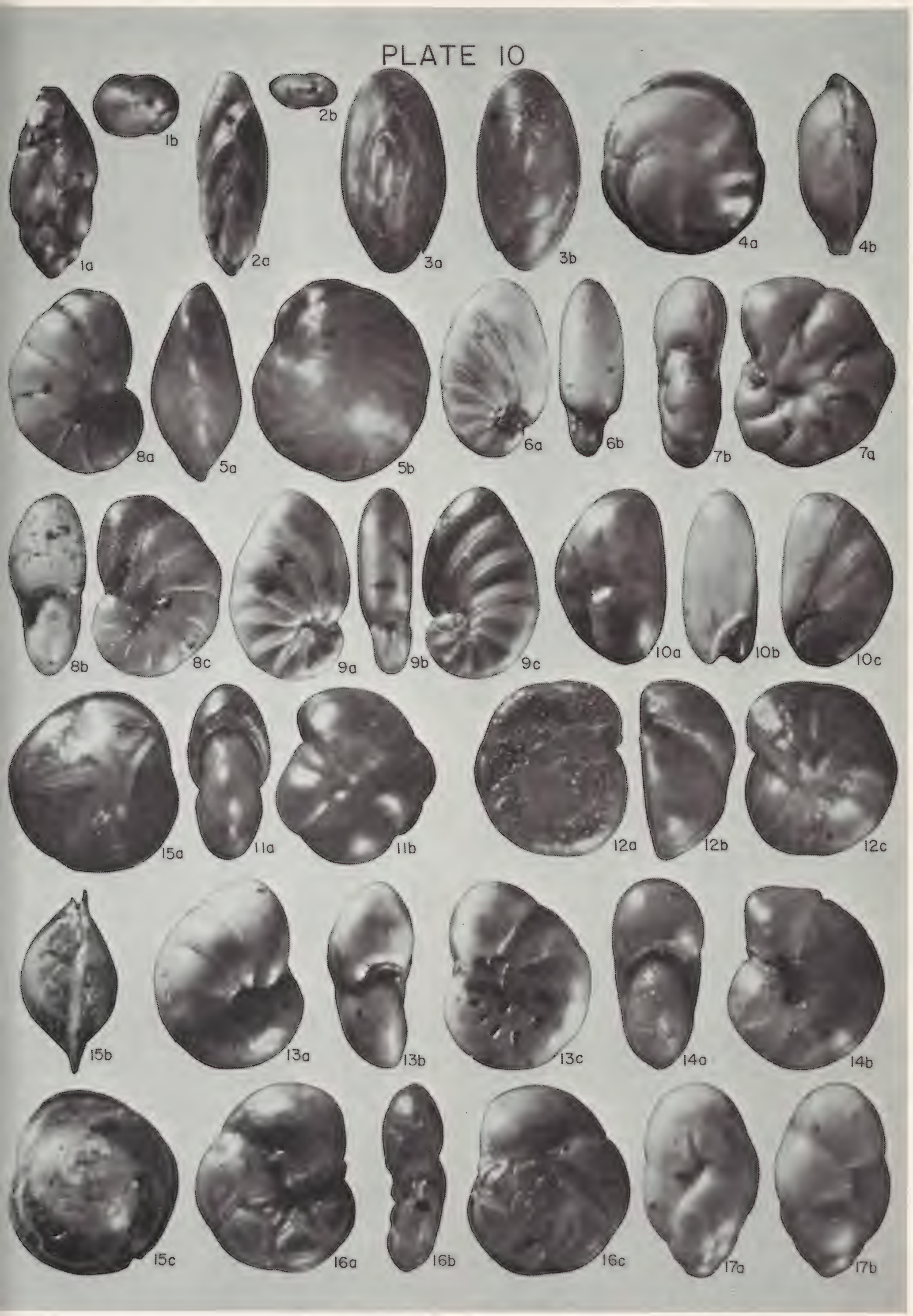
PLATE 10
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PLATE 10

America, Mem. 46, pt. 2, p. 25, pl. 13, figs. 11, 12.

*Webbinella concava* (Williamson) (Plate 4, Figure 12); *Polymorphina lactea* (Walker & Jakob) var. *concava* Williamson, 1858, Rec. Foram. Gt. Britain, p. 72, pl. 6, figs. 151, 152.

*Wiesnerella auriculata* (Egger) (Plate 2, Figure 9); *Planispirina auriculata* Egger, 1893, Abhandl. k. bay. Akad. Wiss., München, vol. 18, pt. 2, p. 245, pl. 3, figs. 13–15.

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April 12, 1971

## RECENT BOOK

THE COURSE OF EVOLUTION, by J. Marvin Weller. Published by McGraw-Hill Book Company, New York, 1969, xxvi + 696 pp., $15.50

This book presents evolution in a clear and comprehensive way at a level which can be understood without a broad background of specialized knowledge of paleobiology. It demonstrates how living organisms have slowly undergone change through long expanses of time adapting to the constantly changing environment, but admitting to gaps in our knowledge and understanding of evolution and to the inevitable incompleteness of the rock record. It is written from the paleontologist's point of view and emphasis is placed on organisms with a fossil record.

# A NEW CORAL FROM THE BUCATUNNA CLAY (MIDDLE OLIGOCENE) OF ALABAMA

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## Abstract

A new ahermatypic coral, *Paracyathus macneili* is described, illustrated, and compared. The species occurs in the Bucatunna Clay Member of the Byram Formation, and is considered a guide fossil of that member. A condensed stratigraphic account of the Byram Formation is also presented.

## General Remarks

On 12 March 1962, the writer collected several highly fossiliferous samples of the Bucatunna Clay in two headwater tributaries of Rock Pit Branch, located 3.2 miles southwest of the town of Monroeville, Monroe County, Alabama. The Bucatunna Clay, which is the upper member of the Byram Formation, contains numerous micromollusks and an assortment of macrofossils; among the latter is a hitherto undescribed coral for which the name *Paracyathus macneili* is proposed.

Two well preserved specimens of *Paracyathus macneili* were found—the holotype in the east-flowing headwater tributary of Rock Pit Branch, and the paratype 0.35 miles to the southeast, near the headwaters of Rock Pit Branch itself. These locations may be spotted on Plates 1 and 2 of John B. Ivey's report on the geology and ground water in the Monroeville area, Alabama, in Bulletin 66 of the Geological Survey of Alabama, 1957.

The Bucatunna Clay in the two streams visited consists of "dark-blue-gray to brown massive, blocky clay, locally containing lenses of clayey, glauconitic sand. These lenses usually contain abundant micro- and macrofossils . . . Wells a short distance southwest of Monroeville, in the Mexia area, penetrate more than 50 feet of Bucatunna." (Ivey, 1957, p. 88, 89). At least 22 feet of the Bucatunna are exposed in the first of the two streams mentioned above, and there the Clay rests conformably on a hard, orange to brown, fossiliferous limestone. This limestone, some 5 feet or so in thickness, is the Marl Member of the Byram Formation, and grades below into the hard, gray, fossiliferous Glendon Limestone, or basal member of the Byram. The contact between the Bucatunna Clay and Marl Member is at stream level, the water flowing underground into the limestone. The holotype of *Paracyathus macneili* was collected in the Bucatunna about 150 feet upstream from, and 2 feet stratigraphically higher than, the top of the Marl Member.

In the second stream, the paratype of *Paracyathus macneili* was collected in a highly fossiliferous sand lens of the Bucatunna, approximately 250 feet downstream from the headwaters of Rock Pit Branch. Here, according to my notes, at least 20 feet of Bucatunna are exposed, with the fossiliferous lens occurring near the base, a foot or so above water level. This lens is estimated to lie about 20 feet above the contact with the Marl Member, and indicates that *Paracyathus macneili* has a vertical range of 20 feet or more from the base of the Bucatunna upward. The Bucatunna in the Monroeville area is overlain disconformably by the Citronelle Formation, an unfossiliferous deposit of sand, gravel, and clay, possibly Pliocene in age.

The Bucatunna Clay Member was first described by Blanpied and others (1934, p. 12–16, correlation chart) in southeastern Mississippi. It was later recognized in southwestern Alabama by MacNeil (1944, p. 1316, 1332–1341; 1946, p. 51, 52, 55), by Murray (1952, p. 700, 702), and by Ivey (1957, p. 84–90, pl. 12). The fossils illustrated on Plate 12 of the last reference were identified by MacNeil, and include the coral discussed in the present paper. The Bucatunna Clay in Mississippi was first assigned an early Miocene age on the basis of "the erosional break at the base of the Bucatunna Member and the Miocene character of the overlying Chickasawhay members" (Blanpied, 1934, p. 16). However, in the correlation chart of Blanpied's paper, prepared by Hanna and Gravell, the Bucatunna is shown in the middle of the Oligocene. Today (see Keroher and others, 1966, p. 511) the Bucatunna, on the evidence of the Mollusca it contains and

on the Foraminiferida in the Glendon Limestone, is believed to be Oligocene in age; its medial position in that epoch has been determined by its stratigraphic relationship.

## Paracyathus macneili, n. sp.
Text-figs. 1–6

*Balanophyllia* aff. *B. caulifera* (Conrad). MacNeil *in* Ivey, 1957, p. 90, 107, Pl. 12, fig. 9.

There are two coralla in the collection, both attached at the base. Specimen OBC-1a, the holotype, is solitary and subtrochoid; specimen OBC-1b, the paratype, consists of two corallites, a larger tympanoid form and a small conical bud developed from the end zone of the former. The holotype is elongate conical and slightly curved, the sides gently expanded and constricted alternately to near the base, the base flared over a shell (pelecypod ?) to which it is adherent. The base of the larger corallite of specimen OBC-1b is also attached to a shell, probably a gastropod; however, the calice of that corallite is so broken and poorly preserved, that although I think it may well be a mature *Paracyathus macneili,* I cannot be certain. On the other hand the smaller corallite does seem to be an immature form of *Paracyathus macneili,* and in its mode of growth appears to be a "bud" of the larger corallite. The lower end of the small corallite is imbedded in the side of the larger but is separated elsewhere.

The calice is subcircular in the young, broadly and regularly oval in the adult, on which the calicular margin is curved outward a little. On the holotype there are 48 septa in four complete cycles, all of the septa exsert in varying degree, dentate along the free margin, and papillate on the sides. The primary and secondary septa are subequal and thickly laminar, with summits more broadly rounded and more strongly exsert than the others; third cycle septa are somewhat smaller than the principals, and the quaternaries slightly smaller than tertiaries. In contrast with the evenly rounded upper half, the lower half of the septa of the first three cycles is erose or paliform along the free margin. The septa of the first two cycles, and to a lesser degree those of the third, are very slightly convex; on the convex side, the upper row of papillae or granules ascend from the wall, then merge to form a ridgelet which runs subparallel with, and a little below, the free margin of the exsert portion of the septum; farther within, the ridgelet merges with and parallels the margin rendering it unequally bipartite, with the true margin the more prominent. There is a tendency for this same process to develop weakly on the concave side of the principal septa, and on those the septal margin may be tripartite. These ridgelets, however, are not present on the younger and smaller corallite of the paratype which has only 38 septa and is obviously immature.

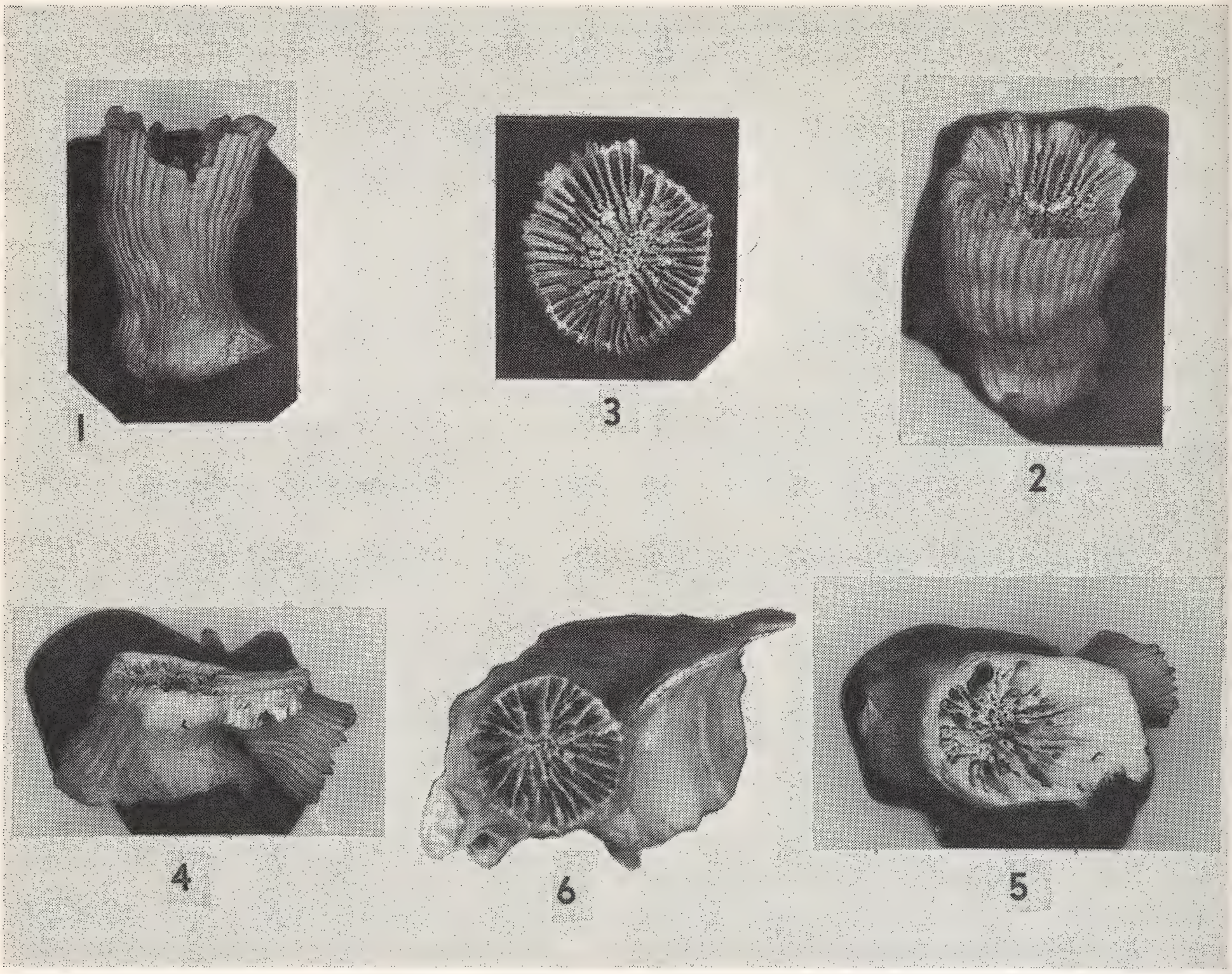
The pali are prominent and occur before the septa of the first three cycles. They are coarsely granular and frondose, extending from about half way down the calice to the columella with which they merge; on some septa they reflect the lobate nature of the lower margin but on others they are present in a single column to the edge of the columella. In general the pali are thicker above than below.

Although each costa corresponds with a septum, the costae are not particularly differentiated by septal size, and on both specimens the costae are nearly equal. The costae may be sharply crested and separated by wide and relatively deep intercostal furrows, or gently rounded and separated by narrow and shallow interspaces. Toward the base the costae may become disjointed and irregular on the solitary corallum, or where corallites are joined, the costae may be swirled and confluent. Like the septa, the crest and sides of the costae are closely granulose.

The columella is relatively broad, papillose, deep, and porous.

*Measurements.* — Holotype (OBC-1a): height 14 mm, calice diameters 9.7 mm × 8.3 mm, depth of calice 6 mm, septa 48. Paratype (OBC-1b): parent corallite (worn down) height 6.5 mm, calice diameters 10 mm × 7 mm; bud height 5.3 mm, calice diameters 5.3 mm × 5 mm, septa 38; corallum length 14 mm, width 9.5 mm, height 7 mm.

*Localities.*—Holotype (OBC-1a): east-flowing headwater tributary of Rock Pit Branch in the SW¼ NW¼ SW¼ Sec. 4, T6N, R7E, of the Monroeville quadrangle, Monroe County, Alabama. Bucatunna Clay, about 2 feet above contact with the Marl Member of the Byram Formation. Paratype (OBC-1b): near headwaters of Rock Pit




Text figures 1–6. *Paracyathus macneili,* n. sp. Figs. 1–3 (holotype), × 2.5. Fig. 1, side view; fig. 2, upper view; fig. 3, calice. Figs. 4–6 (paratype), × 2. Fig. 4, corallum in normal growth position showing parent corallite and bud; fig. 5, calicular view of parent; fig. 6, calicular view of bud.

Branch in the SW¼ SE¼ SW¼ Sec. 4, T6N, R7E, Monroeville quadrangle. Bucatunna Clay, an estimated 20 feet above contact with the Marl Member of the Byram Formation. Collections by Norman E. Weisbord, 12 March 1962.

*Formation and Age.*—Bucatunna Clay Member of the Byram Formation. Middle Oligocene.

*Comparisons.*—This species is undoubtedly the one illustrated by Ivey (1957, pl. 12, fig. 9) and designated by MacNeil as *Balanophyllia* aff. *B. caulifera* (Conrad). The type specimens in the Florida State University collection from the type locality are relatively well preserved and seem to me to be a new species in the genus *Paracyathus* which I am pleased to name *Paracyathus macneili* after Francis Stearns MacNeil.

*P. macneili* is characterized by the subsidiary ridgelet along the free margin of the principal septa, and by its prominent pali. It is similar to *Paracyathus granulosus* Vaughan (1900, p. 107, pl. 8, figs. 15–15b) from the lower Eocene at Woods Bluff, Alabama, but among other differences the pali are much less prominent than in the Bucatunna form.

*Repository.*—The holotype and paratype of *Paracyathus macneili* are presently held in the Department of Geology, Florida State University, Tallahassee, Florida.

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April 12, 1971

# PALEONTOLOGICAL NOTES

## A PECCARY FROM THE PLEISTOCENE OR HOLOCENE OF MISSISSIPPI

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Fossil peccaries have not been reported previously from Mississippi or Louisiana. O. P. Hay (1923) indicates no finds in these states on his map of the distribution of Pleistocene peccaries in eastern North America. Arata (1964) stated that:

> Although peccaries are known from the Pleistocene of Texas, Arkansas and Florida, and may well have occurred in Louisiana, no material to substantiate their presence has been reported to date.

Daryl P. Domning (1969) does not mention peccaries in his list of species of fossil vertebrates reported from Louisiana and Mississippi except for a mistaken report by Brown (1938) which was corrected by Arata (1964).

In December, 1969, geology student Randle E. Roberts, Jr. found the peccary bones here reported partially buried below almost three feet of soil in a road cut on the Mississippi State University campus behind the biology building. Only two elements were found, although digging was done in an effort to find more. The elements, which Roberts states were found buried within three inches of each other, are diagnostic metapodials III and IV, and, although disarticulated, apparently belonged to the same extremity. Because of the lack of comparative material it has not been determined whether the bones are metatarsals or metacarpals. After examining the bones, Dr. Clayton E. Ray, Division of Vertebrate Paleontology, U. S. National Museum, Washington, D. C., confirmed their identification as peccary material.

Figure 1 shows what remains of the peccary metapodials after 9 mm of the proximal end including the articulating surface, had been removed from the longer fossil in order to make chemical tests. The original length was 89 mm. The shaft of the other metapodial was broken when found. The well-preserved condition of the distal epiphyses indicates the specimen belonged to a mature peccary. These specimens have been given the catalogue number 53 I 1[1] and will be in the possession of the Dunn-Seiler Geological Museum at Mississippi State University.

[1] 53 refers to Oktibbeha County which is 53rd in the state alphabetically, I is the symbol for fossil peccary, and 1 indicates that this peccary bone is the first to be found in Oktibbeha County.

Figure 1

Roberts found the peccary bones in soil a few inches above underlying Upper Cretaceous marl. At this level the pH is neutral and favorable to fossilization of bone material. The soil of the present surface approximately three feet above the peccary level is too acid to preserve bone.[2] Assuming that the same difference in pH existed during the Pleistocene, the interesting question presents itself as to how the bones quickly reached the level favorable for fossilization. I am currently studying this problem in adjacent Lowndes County, Mississippi where a number of Pleistocene fossil fragments more characteristic of the known Pleistocene fauna of Mississippi have been found on elevated ridges and under similar conditions.

[2] Personal communication with Dr. Harvey B. Vanderford and Dr. Rollin C. Glenn, Agronomy Department at Mississippi State University.

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## RECENT BOOK

GEOLOGY OF MICHIGAN, by John A. Dorr, Jr., and Donald F. Eschman. Published by The University of Michigan Press, Ann Arbor, 1970, viii + 476 pp., $15.00

This is a synthesis of the geology of a single state, an unusual approach, but an interesting one. Following the introduction, the authors describe the geology of the state and explain its principal geological features and historical development, followed by its mineral resources and chapters dealing with the main types of rocks and fossils found in the state. It is well illustrated and pleasingly arranged.

# AN ADDITIONAL NOTE ON THE FORAMINIFERAL GENUS *GLAUCOAMMINA* AND *REOPHAX CARIBENSIS*[1]

GEORGE A. SEIGLIE[2]

and

PEDRO J. BERMÚDEZ[3]

The foraminiferal genus *Glaucoammina* was described by Seiglie and Bermúdez (1969), with *Reophax trilateralis* Cushman as type-species. Three different forms of this variable species were included in the original description of the genus. One of the forms consists of a triserial-uniserial form with an undetermined initial portion. The second form has an initial, slightly twisted, spiral form, that it is interpreted as a trend toward trochospiral. The third form is the first objective of this note. It consists of an initial enlarged portion followed by two to three uniserial chambers. The second and sometimes the third chamber are smaller than the initial portion. No thin section was obtained of the initial portion and it was originally interpreted as probably trochospiral. Re-examination of the material, however, permits another interpretation: the initial portion is considered as the enlarged first chamber of a megalosphaeric form. This uniserial form is *Reophax*-like.

*Reophax depressus* Natland is considered conspecific and a junior synonym of *Glaucoammina trilateralis* (Cushman), and probably *Reophax irregularis* Parker is also a junior synonym.

*Reophax caribensis* was described by Seiglie and Bermúdez (1969). The second objective of this paper is to emphasize the differences between this species and "*R. scorpiurus* Montfort." Foraminifers identified as *R. scorpiurus* have been illustrated by many authors, the most interesting references for the purpose of this paper are: Brady (1884), Cushman( 1920, 1921), Höglund (1947), Parker (1960), Boltovskoy (1961), Le Campion (1969) and others. Brady (1884) illustrated several specimens of "*R. scorpiurus*," however, the two Atlantic specimens (figures 12 and 14, plate 30) appear to be two different species, and none of the Atlantic specimens is conspecific with any of the Pacific (figures 15 to 17, plate 30). Höglund (1947) illustrated some specimens that he mentioned as ? *Reophax scorpiurus* Montfort, remarking about them, page 81: "It may nevertheless be disputed whether an absolute identity really exists here with what Montfort, 1808, intended by his denomination." Cushman (1920) illustrated several specimens that were examined by one of the writers at the U. S. National Museum, and at least, the Jamaican specimens, one of which is illustrated in figure 5 (plate 1), were not conspecific with the ones illustrated by figures 6 and 7 (plate 1). None of the specimens illustrated by these authors is similar to *R. caribensis* Seiglie and Bermúdez. Le Campion (1969) illustrated several specimens identified as *R. scorpiurus* Montfort that appear to be somewhat similar to *R. caribensis.* He listed in his synonymy only the determinations made by Brady (1884) and Höglund (1947). It is not possible, however, to say from Le Campion's illustrations whether the population is closer to *R. caribensis* or to "*R. scorpiurus*" (according to Höglund). In any case it is concluded from the discussion above that "*R. scorpiurus* Montfort" must be considered a *nomen dubium.*

[1] This paper was sponsored in part by the U.S. Atomic Energy Commission under contract AT(40-1)-1833.

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[3] Departamento de Geología, Universidad Central de Venezuela y Ministerio de Minas e Hidrocarburos, Caracas, Venezuela.

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## REVIEWS

CONTRIBUTIONS TO THE HISTORY OF GEOLOGY, edited by George W. White, a series of classical works in geology, reprinted in facsimile with introductory biographical and bibliographical commentaries by the editor and other distinguished students of the history of geology. These volumes are handsomely and skillfully reproduced and were carefully selected to make essential but almost unobtainable titles available to students and historians at relatively modest cost. Published by Hafner Publishing Company, Inc., New York and London.

1. THE AMERICAN MINERALOGICAL JOURNAL: being a collection of facts and observations tending to elucidate the mineralogy and geology of the United States of America, conducted by Archibald Bruce, M. D. Volume 1 (all published), New York, 1810–1814 [1968], 270 pp. + index. Introduction by John C. Greene, foreword by George W. White. $18.00

This journal was the first American publication designed primarily for geologists and mineralogists. It provides a valuable view of American geologic thought and activity in 1810–1814 as almost every active worker interested in geology and mineralogy contributed to its pages.

2. A VIEW OF THE SOIL AND CLIMATE OF THE UNITED STATES OF AMERICA: with supplementary remarks upon Florida; on the French colonies on the Mississippi and Ohio, and in Canada; and on the aboriginal tribes of America, by C. F. Volney. Translated with occasional remarks, by C. B. Brown. Philadelphia, 1804 [1968], 446 pp. + 2 maps, 2 plates. Introduction by George W. White. $20.00

Volney's classic work was published first in French in 1803. This translation is the earliest significant account in English of the geology of the United States. Volney based his clear descriptions on his own observations rather than preconceived theories. He was personally acquainted with Thomas Jefferson and William Maclure and he freely credited much of his geological information to Samuel L. Mitchell and others. Brown made alterations in the original text and added annotations and explanatory notes to the English version.

3. THE MONTHLY AMERICAN JOURNAL OF GEOLOGY AND NATURAL SCIENCE; exhibiting the present state and progress of knowledge in zoology, botany, mineralogy, comparative anatomy, chemistry, meteorology, physical natural agents, and the antiquities and languages of the Indians of this continent, conducted by G. W. Featherstonhaugh. Philadelphia, 1831–1832 [1969], 576 pp. + 15 plates. Introduction by George W. White. $25.00

George William Featherstonhaugh [pronounced "Fanshaw"] was one of the most widely traveled and versatile early American geologists. He had intimate experience with English and continental geology and visited localities in the field with both Sedgwick and Murchison. In 1831 he founded this journal which through its brief twelve month existence became noted for its scholarly content and for its penetrating reviews of both American and foreign publications often quite different from those appearing in other journals. A number of authors other than the editor contributed to this journal. Especially significant are William Coopers's paper on Big Bone Lick, Jacob Green's "Synopsis of trilobites of North America" and Featherstonhaugh's paper on the drainage of North America and the origin and retreat of Niagara Falls.

4. THE PRODROMUS OF NICOLAUS STENO'S DISSERTATION CONCERNING A SOLID BODY ENCLOSED BY PROCESS OF NATURE WITHIN A SOLID, an English version with an introduction and explanatory notes by John Garrett Winter, with a foreword by William H. Hobbs. The Macmillan Company, New York, 1916 [1968], vii, pages 169–283, plates v–xi (University of Michigan Humanistic Studies, Vol. XI, part 2). Introduction by George W. White. $12.50

The importance of Steno's *Prodromus* is quite well known and requires no elaboration. It was first published in Latin in 1669 and first translated into English in 1671. This modern English translation of 1916 is excellent and definitive and is accompanied by valuable explanatory notes, a brief biography of Nicolaus Steno, a list of his writings, a bibliography of the *Prodromus*, and a most useful index.

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A BIBLIOGRAPHY OF AMERICAN NATURAL HISTORY: The pioneer century, 1769–1865, by Max Meisel. Published by the Hafner Publishing Company, New York and London, facsimile reprint of the edition of 1924, 1967, 3 vols., 1734 pp., $50.00 set

This work by the late Max Meisel is far more than a bibliography. The rise and progress of natural history in the United States is traced from the formation of the American Philosophical Society at Philadelphia in 1769 to the close of the Civil War in 1865. Volume 1 is an annotated bibliography of publications relating to the history, biography and bibliography of American natural history and its institutions during colonial times and the "pioneer century" published up to 1924. In volumes 2 and 3 the institutional bibliographies are arranged according to the dates of foundation and each is preceded by a brief history of the subject organization. This standard work is an indispensable tool to those doing research in natural history as well as to historians and bibliographers.

AN INTRODUCTION TO THE NATURAL HISTORY OF THE TERRESTRIAL SPHERE principally concerning new islands born from the sea and Hooke's Hypothesis of the Earth on the Origin of Mountains and Petrified Bodies to be further established from accurate descriptions and observations, by Rudolf Erich Raspe, translated and edited by Audrey Notvik Iversen and Albert V. Carozzi; and including a facsimile reprint of *Specimen Historiae Naturalis Globi Terraquei*, the original 1763 edition. Published by Hafner Publishing Company, New York, 1970, $19.50

Unfortunately, Rudolf Erich Raspe is remembered not for his considerable contributions to geology, but as the author of the celebrated work of fiction "Baron Munchausen's Narrative of his Marvellous Travels and Campaigns in Russia." This, the first English translation of his most important geologic work, should serve to focus attention on his scientific efforts. *Specimen Historiae Naturalis Globi Terraquei* . . . is far more than an expanded illustration of Hooke's work; it blends the concepts of others with his own original contributions to structural geology, a knowledgable and critical review of newly formed mountains and islands, and produces a theory of the earth which achieved a notable degree of success in its own time.

SIR CHARLES LYELL'S SCIENTIFIC JOURNALS ON THE SPECIES QUESTION, edited by Leonard G. Wilson. Published by Yale University Press, New Haven and London, 1970, lxiv + 572 pp., index, $17.50

This exciting volume is an extremely important contribution to the understanding of one of the most significant events in the history of biology. It presents the text of the seven notebooks in which Sir Charles entered his notes, his thoughts on the mutability of species, and extracts from his correspondence with Charles Darwin from 1855 until 1861 when he began to write his own manuscript for the *Antiquity of Man.* These notebooks provide intimate insight into Lyell's intellectual struggle with the many complexities introduced by Darwin's concept of natural selection to the interpretation of geological history.

On April 16, 1856, at Down House, Darwin and Lyell discussed the species question for the first time and Darwin explained his theory of natural selection. Sir Charles recorded this discussion including an outline of the main features of the theory in his journal. He immediately and very strongly urged Darwin to publish his theory and continued to do this on subsequent occasions. The journals faithfully record the day by day progress of Lyell's thinking and his response to the theory and to criticisms of Darwin's concepts. It is hoped that this book will lay to rest the irritating, erroneous, and frequently stated idea that Sir Charles obstinately resisted evolutionary theory. He knew full well the dramatic impact that publication of Darwin's work would have on their contemporaries. It seems to this observer that Lyell assumed the role of devil's advocate to stimulate Darwin's response to criticism and thus to polish his exposition of natural selection while continuing to urge him to publish the theory. Lyell's own position is summarized by Dr. Wilson in these words: "In Lyell's cautious judgment, the consequences of Darwin's theory were so comprehensive and staggering that it required an equally comprehensive study of its implications for every aspect of the world of living nature. Moreover, Lyell was sensitive to questions inherent in Darwin's theory that might have escaped a less critical mind."

An extensive introduction precedes the text of the seven notebooks. In it, the editor traces the development of Lyell's thinking on species prior to the first of the journals and recounts the events in his life in the years during which he wrote the journals. Dr. Wilson's notes which are inserted following each journal are scholarly and exceedingly valuable. This volume is a contribution to the history of science of first rank importance.

THE EARTH IN DECAY: A History of British Geomorphology, 1578–1878, by Gordon L. Davies. Published by American Elsevier Publishing Company, Inc., New York, 1970, xvi + 390 pp., $16.00

This book traces the evolution of British thought on the origin of the Earth's topography, now termed geomorphology, from the publication of Bourne's *Treasure for Travellers* in 1578 until 1878 by which time the concept of subaerial denudation was firmly established in Britain in essentially its modern context. Of special interest is the elucidation of the amount and scope of pre-Huttonian literature which contains significant geomorphic subject matter. The author has included a bibliography which lists the more important of these early titles, many of which have not previously been considered as source material for study of geomorphology.

THE GEOLOGY OF WESTERN EUROPE, by M. G. Rutten. Published by Elsevier Publishing Company, Amsterdam, London and New York, 1970, xviii + 520 pp., $22.50

Consideration of the Geology of Europe is complicated by the many countries involved and by the differences in training and viewpoint which geologists of different nationalities possess. Professor Rutten has attempted to produce an overall view of the geology of Western Europe without neglecting to discuss the varied nature of contemporary geological thinking and the present controversies which exist among European geologists. He chose to limit his treatment to discussion of certain areas selected to highlight the main aspects of European geology. This reviewer feels that he has accomplished these purposes quite well. The book is large in format, quite well illustrated and modestly priced for its quality and content.

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April 12, 1971

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# TULANE STUDIES IN GEOLOGY AND PALEONTOLOGY

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## PLANKTONIC FORAMINIFERA AND BIOSTRATIGRAPHY OF SOME NEOGENE FORMATIONS, NORTHERN FLORIDA AND ATLANTIC COASTAL PLAIN

W. H. AKERS
*Chevron Oil Company, New Orleans*

p. 1

TULANE UNIVERSITY OF LOUISIANA
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# TULANE STUDIES IN GEOLOGY AND PALEONTOLOGY

Volume 9

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HUBERT C. SKINNER
*Editor*

EMILY H. VOKES
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W. H. AKERS
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## I. ABSTRACT

Planktonic foraminifera are identified and illustrated (by scanning electron photomicrographs) from the Chipola, Yellow River, Red Bay, and Jackson Bluff formations of northwestern Florida. Similar studies of material from Yorktown and Waccamaw localities on the coastal plains of the eastern United States, the Moín Formation of Costa Rica, and the Encanto and Agueguexquite formations of Mexico indicate stratigraphic relationships, which are different from the ages and correlations previously proposed for some of these strata based on other criteria. The calcareous nannofossil genera *Discoaster, Catinaster,* and *Sphenolithus,* were also included in the present studies.

Comparative ranges of these microfossils indicate a Burdigalian age for the Chipola Formation, a late Langhian age for the Encanto and Yellow River formations, a Tortonian to Messinian age for the Red Bay Formation, and an early to middle Pliocene age for the Jackson Bluff, Yorktown, and Agueguexquite formations. Material from several localities assigned to the Waccamaw Formation are correlated with the Moín Formation of Costa Rica for which an early Pleistocene age is indicated.

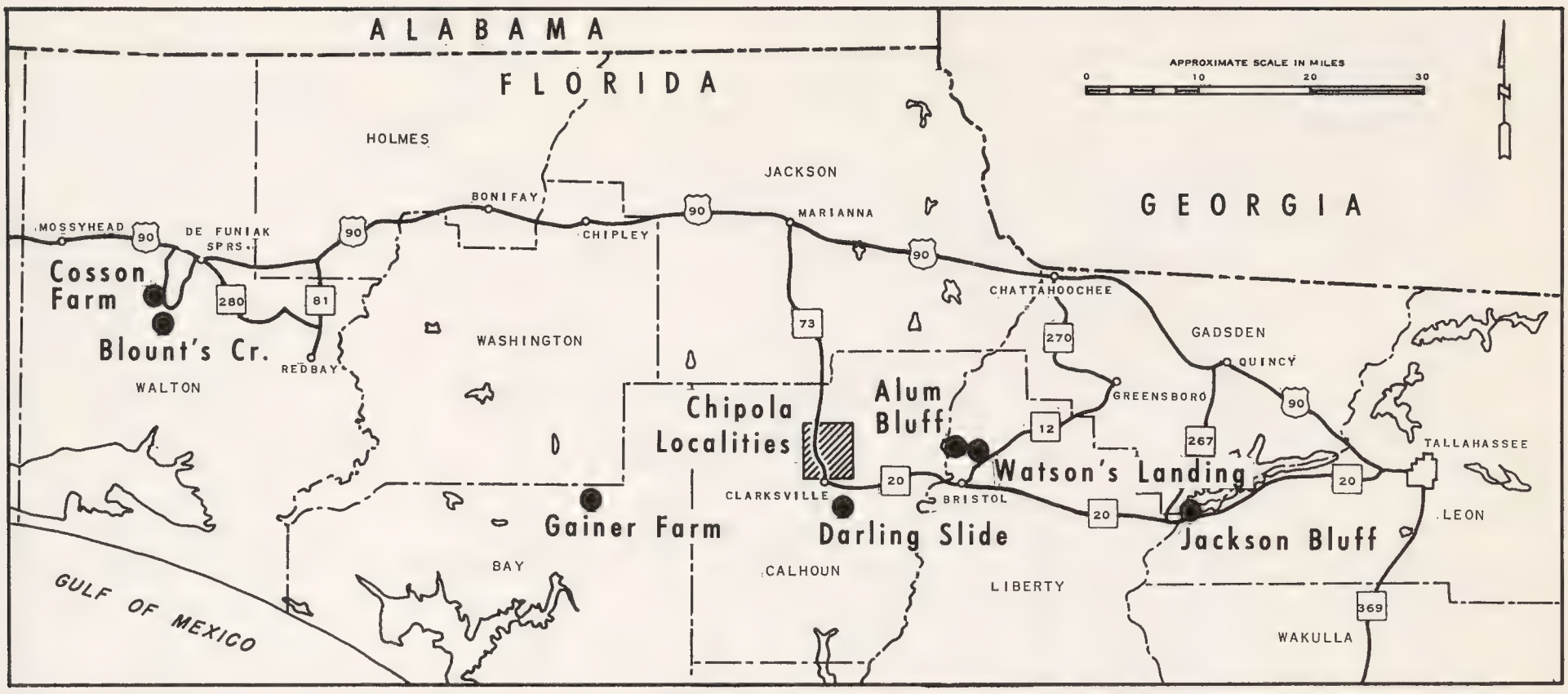
A total of 52 species and subspecies of planktonic foraminifera were identified from these Neogene formations. One of these species, *Globorotalia (Globorotalia) praeoscitans* is new. This report is intended primarily as documentation of planktonic foraminifera from some American formations which long have been neglected by specialists on this group of fossils.

## II. INTRODUCTION

Neogene formations of northern Florida hold interest for the biostratigrapher, who must look to these sediments as the nearest accessible marine strata that are equivalent to the subsurface oil-bearing beds of the northern Gulf of Mexico, which attain thicknesses in the subsurface of 20,000 feet and more.

Malacologists, who have correlated the macrofaunas from classic localities in northern Florida with assemblages from outcrops in the Atlantic Coastal Plain and the West Indies, long have been aware, however, that morphologic similarities are related to similarities of depositional environment as well as time. It was with such problems in mind that Cooke, Gardner, and Woodring (1943, p. 1713) cautioned that "there is little basis for an exact correlation between the Cenozoic formations of the Atlantic and Gulf Coastal Plain and the Caribbean region on the one hand and the European standard section on the other."

The development of stratigraphic nomenclature for the Florida Neogene began with Conrad (1846, pp. 36-48; pp. 399-400) who considered some of these rocks to be of late Eocene age. Tuomey (1851, pp. 390-4) agreed with Conrad, but Heilprin (1884, pp. 115-154; 1887) proposed an Oligocene age for these same beds.




Map 1. Choctawhatchee and Chipola localities of northern Florida from which planktonic microfossils have been identified.

Many of the localities were made famous by the molluscan studies of Julia Gardner (1926-1950) and W. C. Mansfield (1930-1937), and of Joseph A. Cushman and G. M. Ponton (1932) on the foraminifera. These authors were largely responsible for the standard middle Miocene section of North America. Puri (1953, p. 15) reviewed the stratigraphic terminology applied to Neogene rocks in northern Florida and pointed out that early age determinations were based on erroneously identified fossils and that little was known in regard to stratigraphy. Encouraged by Vernon (1942), Puri (1953) recognized the Tampa Stage of early Miocene age, the Alum Bluff Stage of early and middle Miocene age, and the Choctawhatchee Stage of middle and late Miocene age. Certain formations were reinterpreted as lithofacies, and zones were redefined as faunal facies. Subdivisions of each stage were considered contemporaneous (see Figure 1). This treatment seemed, indeed, the logical and most conservative interpretation of beds for which there are few and scattered outcrops.

The exact relationships of the discontinuous Neogene beds exposed in the Florida panhandle can be established by three types of data, (1) absolute dating methods, (2) refined knowledge of the evolution of taxa (*e.g.,* Vokes, 1965), and (3) the sequence of planktonic microfossils. This study employs the last of these methods. The ideal solution would be based upon all three methods with aid from paleomagnetic data.

Work on fossil planktonic assemblages during the last fifteen years has resulted in recognition of over 50 distinct faunal zones in Cretaceous and Tertiary strata. "These zones appear in the same sequence around the world" (Tappan and Loeblich, 1968, p. 1348). Several classic localities have long been known to have a moderate frequency of planktonic foraminifera, but this group was omitted or treated in a cursory manner by the early workers (Cushman, 1918; 1920; 1930; Cushman and Ponton, 1932; Cushman and Cahill, 1933) because of the imperfect knowledge at that time concerning the systematics and evolution of these foraminifers. The planktonic component of foraminiferal assemblages in the Choctawhatchee Formation, for example, was dismissed by Cushman (1930, p. 59) with his remarks on the genus *Globigerina*: "The various species of the genus *Globigerina* used in a restricted sense are in such a chaotic state that it is difficult to treat most of them intelligently. A study of the types with large series of topotype specimens is necessary to straighten out the confusion now existing. There is a very considerable difference in the early and adult stages in most of the species, and unless good series can be obtained,

| | 1 | | | | 2 | | | | 3 | | | 4 | | | 5 | 6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CUSHMAN AND PONTON, 1932 | | | | SMITH, 1941 | | | | VERNON, 1942 | | | COOKE, 1945 | | | PURI, 1953 | CORRELATIONS AND AGES INDICATED BY PLANKTONIC MICROFOSSILS |
| SERIES | STAGE | GROUP | FOR-MATION | FAUNIZONES | STAGE | GROUP | FOR-MATION | FAUNIZONES | GROUP | FOR-MATION | FAUNIZONES | GROUP | FOR-MATION | FAUNIZONES | LITHO – AND FAUNAL FACIES (LIMITS COINCIDE WITH FORMATIONAL AND FAUNIZONAL BOUNDARIES) UPDIP … DOWNDIP | |
| MIOCENE | UPPER | | CHOCTAWHATCHEE | *Cancellaria* zone | UPPER | | CHOCTAWHATCHEE | *Cancellaria* zone | | CHOCTAWHATCHEE | *Arca* AND *Ecphora* AND *Yoldia* AND *Cancellaria* facies | | DUPLIN | *Cancellaria* zone | CHOCTAWHATCHEE STAGE: *Arca* facies, *Cancellaria* facies, *Yoldia* facies, *Ecphora* facies | JACKSON BLUFF FORMATION replaces Ecphora and Cancellaria faunizones; RED BAY FORMATION replaces Arca faunizone; YELLOW RIVER FORMATION replaces Yoldia faunizone |
| | | | | *Ecphora* zone | | | | *Ecphora* zone | | | | | | *Ecphora* zone | | |
| | MIDDLE | | | *Arca* zone | MIDDLE | | | PERMENTER'S FARM BEDS | | | | | | *Arca rubisiniana* zone | | |
| | | | | *Yoldia* zone | | | | *Arca* zone | | | | | | *Yoldia waltonensis* zone | | |
| | ALUM BLUFF | | SHOAL RIVER | *Cardium* bed | ALUM BLUFF | | SHOAL RIVER | *Yoldia* zone | | SHOAL RIVER | | ALUM BLUFF | SHOAL RIVER | | ALUM BLUFF: SHOAL RIVER FACIES, CHIPOLA FACIES, HAWTHORN (EAST OF APALACHICOLA RIVER) FACIES | CALCAREOUS NANNOFOSSILS AND PLANKTONIC FORAMINIFERA RARE OR ABSENT |
| | | | | Middle zone | | | | LOWER BEDS ON SPENCE'S FARM | | | | | | *Glycymeris waltonensis* zone | | |
| | | | | Type zone | | | | *Cardium* bed | | | | | | | | |
| | | | OAK GROVE SAND | Transition zone | | | | Type Shoal River / White Creek beds | | | | | | | | |
| | | | | Type zone | | | | Godwin Bridge beds | | | | | | | | |
| | | | | | | | | Upper Oak Grove | | | | | | *Cardium taphrium* zone | | |
| | LOWER | | CHIPOLA | | LOWER | | CHIPOLA | Type Oak Grove | | | | | CHIPOLA | | OAK GROVE FACIES | CHIPOLA FORMATION |
| | | | TAMPA LIMESTONE | | | | TAMPA LIMESTONE | | | TAMPA | | | TAMPA LIMESTONE | | TAMPA STAGE: CHATTAHOOCHEE FACIES, ST. MARKS FACIES | CALCAREOUS NANNOFOSSILS AND PLANKTONIC FORAMINIFERA RARE OR ABSENT |

| | 6 |
|---|---|
| | CHOCTAWHATCHEE STAGE |
| L–M | ALUM BLUFF STAGE |
| PLIOCENE | MIOCENE |
| U | |
| M | |
| L | |

Figure 1. Correlations of formations in northern Florida. Correlation of columns 1-5 after Puri (1953). Subdivisions of Choctawhatchee Stage in column 6 are by Puri and Vernon (1964).

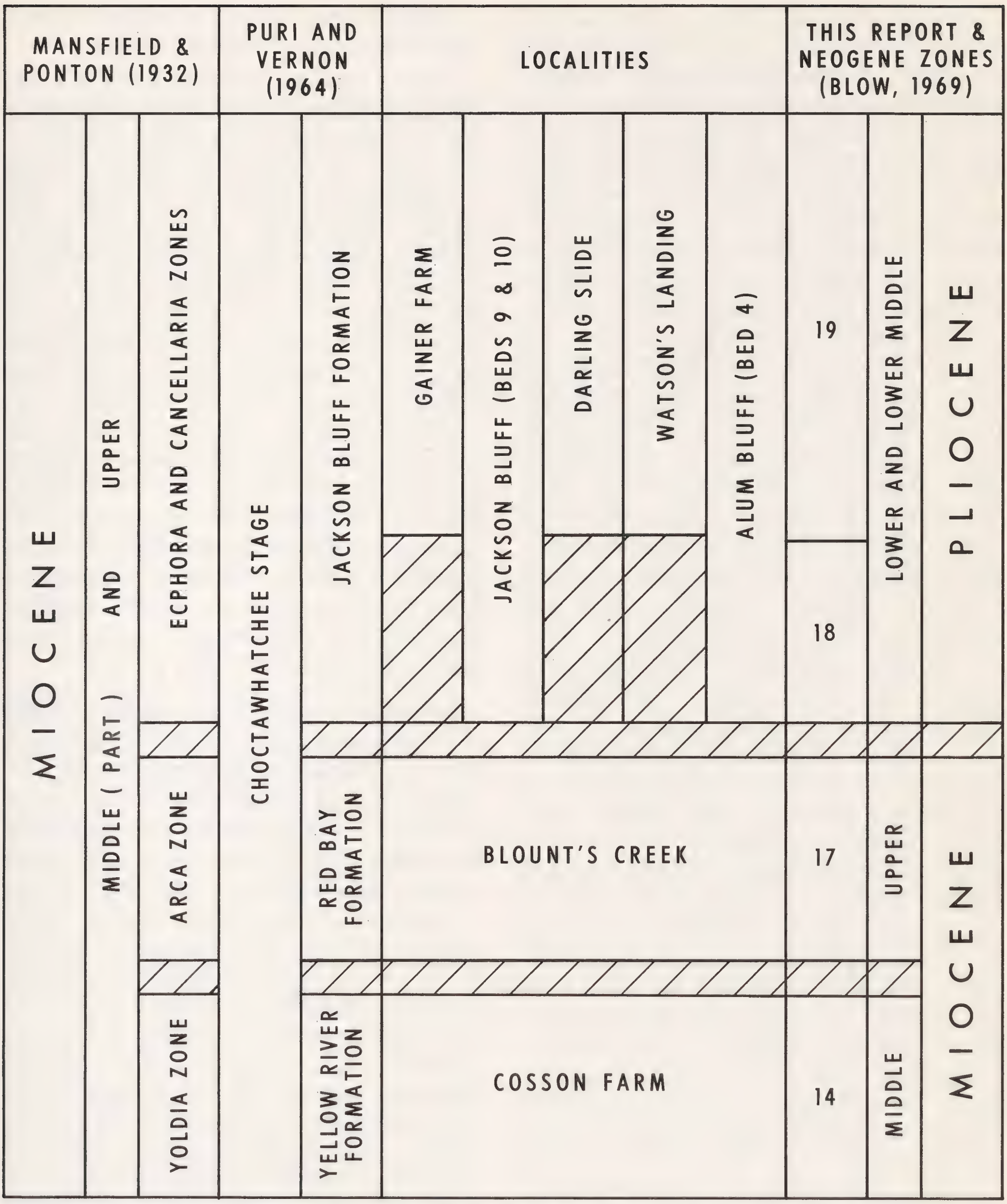



Figure 2. Correlation of some formations of the Choctawhatchee Stage by planktonic microfossils.

descriptions based on a few specimens are worth little. A number of the forms were figured in my earlier work (Bull. 676, U. S. Geol. Survey, 1918, pls. 12, 13), and while some of these were not named or only with a question, they must remain in this unsatisfactory condition until some one available to the types can make a species study of this genus." These early reports, incomplete for the planktonic species, have remained the standard references to the Middle Tertiary foraminifera of Florida.

Planktonic microfossils are rare in much of the Florida Cenozoic, but it was hoped that prolonged examination of sieved, disaggregated material would reveal sufficient planktonic foraminifera or calcareous nannoplankton for identification of at least portions of the section with the sequence established by Blow (1969), Bolli (1966), Bramlette and Wilcoxon (1967), and Gartner (1969). Beds which can be dated by planktonic microfossils are indicated on Figures 2, 3. They are, as pointed out by Puri (1953) and Puri and Vernon (1964), of different litho- and faunal facies. There is strong evidence, however, that the subdivisions of the Choctawhatchee Stage are not contemporaneous, as suggested by these authors, but of different ages. It is interesting that our data indicate the same relative positions as proposed earlier by Mansfield and Ponton (1932, pp. 84-88), although a slightly different correlation with the European time scale is now indicated.

The main purpose of this report is to establish the biostratigraphic interrelationship of Neogene beds in northern Florida which contain planktonic microfossils and to document the occurrence there of planktonic foraminifera which are now known to be useful for the circumglobal correlation of marine sediments (Figures 3 and 4). Several formations of the Atlantic and Gulf of Mexico coastal plains are included because of long interest among stratigraphers in their relationship to the Florida section. The calcareous nannofossil content of these beds also was investigated, and, although this was sparse by comparison with the content of deep-sea cores, nannoplankton corroborate ages indicated by planktonic foraminifera for some of the formations.

Varying quantities of sampled material were prepared for concentration of free foraminiferal specimens. Boiling of original material in a solution of "Quaternary 0" for approximately four hours was found effective for cleaning clay and marly deposits out of the pores and apertures (see Zingula, 1968, p. 1092). This procedure was followed for all samples and produced specimens so clean as to resemble tests of well preserved modern foraminifera.

A U. S. Standard Sieve number 200 was then used for screening out "fines" below the size of identifiable species. The openings in this screen are smaller than the diameter of *Cassigerinella chipolensis* (Cushman and Ponton), which is one of the smallest planktonic foraminifers identified in the Neogene of Florida. No pressure greater than a fine spray of water from the tap was applied to this material because of the fragile nature of the tests, many of which were left hollow from boiling in the "Quaternary 0" solution.

Several samples, such as those from the Waccamaw Formation, were more than 90% quartz sand by volume, and tetrachloroethylene was found useful for separating the calcareous microfossil material from the quartz. The usual procedure for separation by heavy liquid was followed, and the examination time for each sample so treated was reduced from several weeks to a few days.

No set rule was followed for the quantity of residue examined. The search for specimens of planktonic foraminifera was continued for each sample until the writer was convinced that every species representative of the biofacies had been found. For some studies it was necessary to prepare several lots of material. Thus, examination by stereoscopic microscope varied from 20 to 30 hours in the case of fairly fossiliferous residues to more than a hundred hours for those in which planktonic foraminifers were scarce.

Preparation of samples for study of calcareous nannoplankton was essentially the same as described by Bramlette and Sullivan (1961). As with the search for planktonic foraminifera, the examination of material was extended until the writer was convinced that every species representative of the biofacies had been found.

The holotype and paratypes of *Globorotalia (Globorotalia) praeoscitans,* n. sp., are deposited at the U. S. National Museum. All other figured specimens are deposited in the Chevron Collections, New Orleans, Louisiana.

## III. ACKNOWLEDGMENTS

Sample material was collected in northern Florida on several field trips, which were organized and led by Robert O. Vernon and Harbans S. Puri. The writer's participation in these trips and several independent visits to collecting localities in the Florida panhandle were supported by the Chevron Oil Company. Most of the Yorktown, Waccamaw, and Chipola material was supplied by Harold E. and Emily H. Vokes, whose great interest in and knowledge of biostratigraphy of the Gulf of Mexico and Atlantic coastal plains were a constant source of encouragement and guidance. They also furnished abundant other material from Mexico, Central America, and Europe for comparison with Neogene microfaunas of Florida and the Atlantic Coast of the United States.

Hubert C. Skinner gave particular assistance with taxonomic and illustrative aspects of this report, and the writer is indebted to him for both editorial and technical review of all data presented herein.

Paul E. Koeppel and Louisa O. MacLaren of Chevron assisted with the preparation and illustration of planktonic foraminifera. All illustrations are Stereoscan photographs made with a Cambridge scanning electron microscope in the New Orleans laboratory of Chevron Oil Company. The use of the instrument is greatly appreciated.

C. Wylie Poag, formerly of Chevron, now of Texas A. & M. University, examined most of the planktonic foraminifera on which correlations in this report are based, and the writer has benefited from numerous discussions with him concerning taxonomic determinations. Frances L. Parker of Scripps Oceanographic Institute has also seen portions of the material, and the writer has benefitd from her suggestions.

## IV. SUMMARY

Planktonic foraminifera are documented (by scanning electron photomicrographs) from some Neogene formations of the coastal plains of the eastern United States, northwestern Florida, the Isthmus of Tehuantepec, Mexico, and Costa Rica. Both planktonic foraminifera and calcareous nannoplankton are employed in the correlation of these strata with Neogene stages of Italy by means of concurrent-range zones, which have been established by various investigators for many regions of the low and middle latitudes.

Comparative ranges of these planktonic microfossils indicate that the Chipola Formation is of Burdigalian age (late early Miocene). The Encanto Formation of Mexico is correlative with the Yellow River Formation of northwestern Florida, and these are of late Langhian age (middle Miocene). The Red Bay Formation of northwestern Florida is Tortonian to Messinian (late Miocene). Some localities of northwestern Florida, which have long been classic sites for molluscan and benthonic foraminiferal studies represent synchronous deposition and are of early to middle Pliocene age. These localities are referable to the Jackson Bluff Formation and include Alum Bluff (Bed 4), Watson's Landing, Darling Slide, Jackson Bluff (Bed 9 and Bed 10), and Gainer Farm. Several localities referred to the Yorktown Formation have planktonic microfossils which suggest correlation with the Jackson Bluff Formation, and therefore, an early to middle Pliocene age, rather than late Miocene, as long proposed for these beds. The Agueguexquite Formation of Mexico is approximately correlative with the Jackson Bluff and the Yorktown. Two localities assigned to the Waccamaw Formation contain assemblages of planktonic foraminifera that indicate a Calabrian age, and the Moín Formation of Costa Rica must be correlated with the Waccamaw and also referred to the lower Pleistocene.

Samples from the Caloosahatchee, Hawthorn, Shoal River, Trent Marl, and Tampa Limestone formations were examined. Planktonic foraminifera and calcareous nannofossils were rare or absent in all of these. Thus, stratigraphic relationships of the complete Florida and Atlantic Coastal Neogene sequence cannot be established by planktonic microfossils alone.

## V. BIOSTRATIGRAPHY

Blow (1969) has evaluated and summarized much of the Neogene biostratigraphy that is based upon planktonic foraminifera. By supplementing our knowledge of the geologic ranges and evolution of these organisms with data on the ranges of calcareous nannofossils, credible correlations can now be established between widely separated Cenozoic sections, including some of the type sections in Europe. The writer is fortunate in having considerable Neogene topotypic material from the Gulf of Mexico, Caribbean, Mediterranean, and west European regions for comparison with those taxa upon which the age-dating and correlation of various authors are based. Actual specimens are particularly valuable to such comparative studies in view of the varying taxonomic opinions of those who investigate these problems.

Although the primary purpose of this report is to document planktonic foraminifera in some of the Neogene formations of Florida and the Atlantic Coastal Plain and to review the biostratigraphic interrelationships of these beds, the inevitable question arises as to the relationship between the subject formations and the European stages. In recent years world-wide studies by numerous specialists on planktonic foraminifera have been extended into the type European sections, and it is now possible to establish zonations and correlations that appear to be synchronous over long distances validating, for the first time, the use of European stratigraphic terminology in areas remote from the type localities. The recognition of planktonic microfossils for these purposes is a "break-through," particularly for those who have long found the Lyellian percentage method inadequate or spurious as a precise means of determining the age of a Cenozoic formation (see Dall, 1892, p. 215).

A sequence of zones based on evolutionary appearances of circum-equatorial planktonic foraminifera was introduced by Banner and Blow (1965), and boundary positions were related to type localities in Europe. Parker (1967) recognized these successions in Indo-Pacific deep-sea cores and adopted the zones as defined. Further clarification of these zonations and documentation of the European Neogene succession were accomplished in a comprehensive report by Blow (1969), and Berggren (1969) related the sequence (Upper Cretaceous to Pleistocene) to the radiometric time scale, geomagnetic polarity history, and North American mammalian stages. Smith (1969) and Gartner (1969) have related calcareous nanofossil successions in the type Calabrian of Italy and other regions to the foraminiferal zones.

A major limitation to planktonology as the "Rosetta Stone" for Cenozoic biostratigraphy is encountered near the landward margins of depositional basins. As a rule, only the more seaward facies yield sufficient planktonic foraminifera and calcareous nannofossils for age determination. Certain species, as *Sphaeroidinella dehiscens* (Parker and Jones), show an affinity for the deeper layers of oceanic water. This species is typically developed in modern seas only below 300 meters (Bé, 1965, p. 84). *Globigerinatella insueta* Cushman and Stainforth, an excellent guide fossil of short stratigraphic range in the Miocene of the Caribbean and Gulf of Mexico regions, is absent or rare except in deep water facies in the subsurface of both Trinidad and coastal Louisiana. Low-latitude species, such as *Globigerinoides ruber* and *Globigerinoides "sacculifer,"* which abound in the upper-water layers (Berger, 1969, p. 19), are the most likely forms to be found in the littoral zones of modern seas, and by analogy with ancient environments, these or phylogenetically related species, would be expected to dominate the planktonic component of fossil assemblages found in rocks of nearshore origin. This is precisely the case with the formations investigated in this study. The Waccamaw and Chipola Formations contain a predominance of the near-surface planktonic foraminifera over other planktonics, and the planktonic to benthonic ratio is low in both formations. Calcareous nannoplankton are rare in the Chipola and absent in Waccamaw material.

Offshore facies, such as those represented at the Cosson Farm, Blount's Creek, and Jackson Bluff localities of the Choctawhatchee Stage in northern Florida, yield planktonic assemblages which are qualitatively

similar to those in deep-sea cores from oceanic basins. The ratio of planktonic to benthonic total individuals is far less, however, than in deep-sea cores recovered from bathyal or greater depths.

The Caloosahatchee, Hawthorn, Shoal River, Trent Marl and Tampa Limestone formations were found to be almost completely devoid of both planktonic foraminifera and calcareous nannoplankton. Although the writer was tempted to propose interpretations of the stratigraphic relationships of these formations, this report is confined to those beds from which adequate planktonics were derived for correlation with age-dated sections (Berggren, 1969) and sections which have been related to the sequence of planktonic foraminifera as now understood (Blow, 1969; Bolli, 1966).

Temperature is an important controlling factor in the distribution of planktonic organisms. Thus, if the Waccamaw is early Pleistocene, decreasing paleotemperatures of the Atlantic nearshore waters could, along with shallow paleobathymetry, account for the scarcity in this formation of warm water species, such as *Globorotalia cultrata* (d'Orbigny). The Moín, also of early Pleistocene age, is a deposit of greater paleobathymetry and lower latitude, and consequently it has a greater diversity of planktonic species.

Paleotemperatures complicate the correlation of synchronous sediments on an interregional scale. Much has been written in recent years on the world-wide distribution of planktonic foraminiferal species as related to the temperature of water masses (*e.g.*, Bandy, 1964; Bé and Hamlin, 1967; Boltovskoy, 1964 and 1965; Bradshaw, 1959; Parker, 1960). Distributions of the 30 modern species are succinctly summarized by Bé (1966), who recognizes four provinces, each of which is characterized by a group of planktonic species. These are the Equatorial or Tropical species, the Central-water or Subtropical species, the Subpolar species, and a single Polar species. Upwellings and displacement by warm currents result in cross-latitudinal incursions. Thus, it happens that synchronous paleonenvironments may have dissimilar fossil assemblages. We see the same species in middle Tertiary beds of Saipan, for example, as those in the middle Tertiary of the Caribbean and Gulf of Mexico regions, but the middle Tertiary assemblages of California are different. Fortunately, the deposits considered in this study are of tropical and subtropical origin, so that the principal difficulties in correlation are related to paleobathymetry rather than to paleotemperature.

Those formations of the Atlantic and Gulf Coastal Plains of the United States and the formations of Mexico and Costa Rica reviewed for stratigraphic relationships, as indicated by planktonic microfossils, are discussed below.

## CHIPOLA FORMATION
Plates 1-5

Material from 25 localities of the Chipola Formation, Calhoun County, Florida, was examined for planktonic microfossils (Map I and Locality data). All of these are in the general vicinity of the type locality (Dall, 1892, p. 122; Dall and Stanley-Brown, 1894, pp. 140-170; Matson and Clapp, 1909, p. 91; Gardner, 1926, p. 1), where about 28 feet of a blue-gray to yellowish brown, highly fossiliferous marl are exposed. Cushman and Ponton (1932) described the benthonic foraminiferal fauna, and Puri (1953) recorded the ostracodes of the Chipola Formation.

Recently Emily H. Vokes (1965) has commented on the age of the Chipola as indicated by the Muricinae (Mollusca: Gastropoda) suggesting that this formation may be equivalent to the Helvetian of western Europe rather than Burdigalian as indicated and perpetuated in the Geological Society of America correlation chart (Cooke *et al.*, 1943). Gibson (1967, p. 643) looked at several samples from the Chipola and thought that planktonic foraminifera indicated correlation with the *Globigerinatella insueta* Zone of Trinidad, the same zone to which he refers the upper part of the Calvert Formation of Maryland and the Pungo River Formation of North Carolina.

All of the Chipola localities investigated yielded essentially the same planktonic species, although the planktonic to benthonic ratio was higher at some of the sites than at

others. One of the highest ratios was found at TU 951 in Section 12, T1N, R10W, Calhoun County, Florida, and most of the specimens illustrated and discussed in this report are from that locality.

The Chipola Formation contains the following planktonic foraminifera:

*Cassigerinella chipolensis* (Cushman and Ponton), pl. 1, fig. 1; pl. 2, fig. 1
*Globigerinita glutinata* (Egger)
*Globigerinita uvula* (Ehrenberg), pl. 1, fig. 2
*Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny), pl. 3, fig. 4
*Globigerinoides subquadratus* Bronnimann, pl. 4, fig. 3
*Globoquadrina baroemoenensis* (LeRoy), pl. 3, fig. 3; pl. 5, figs. 2-3
*Globoratalia (Turborotalia) obesa* Bolli, pl. 3, fig. 1
*Globorotalia (Turborotalia) siakensis* (LeRoy), pl. 5, fig. 1

In addition to the above species, rare specimens occur resembling *Globigerinoides quadrilobatus altiaperturus* Bolli (pl. 3, fig. 2). These have apertures which are wider than in the typical form. Other small specimens are found which show a superficial similarity to *Globigerinoides sicanus* de Stefani, but none of these have the slit-like apertures characteristic of that species, and most are probably juveniles and aberrants of G. *quadrilobatus quadrilobatus* (pl. 2, fig. 2). A few larger specimens (pl. 4, figs. 1, 2, 4) may be aberrant or gerontic forms.

*Globigerinoides quadrilobatus quadrilobatus* occurs more frequently than any other planktonic foraminifer at all of the Chipola localities investigated. It also attains the largest size of all the forms seen from this formation. *Globigerinita uvula* and *Globigerinita glutinata* (Egger) are rare. A single broken specimen of the latter was found at TU 951. *Cassigerinella chipolensis* occurs at most of the 25 sites, but it is never abundant in even the finest fractions of the residues. *Globorotalia (T.) siakensis, Globorotalia (T.) obesa, Globoquadrina baroemoenensis,* and *Globigerinoides subquadratus* also occur at most of the localities but always in low frequencies.

*Discoaster deflandrei* Bramlette and Riedel, *Braarudosphaera bigelowi* (Gran and Braarud) Deflandre, and small, unidentified coccoliths are found in low frequencies (one specimen per 20 mm of traverse at X500) in preparations of calcareous nannofossil material.

All of the Chipola planktonics, both in foraminiferal and calcareous nannofossil categories, have relatively long stratigraphic ranges. This seems to be a phenomenon common to microplanktonic assemblages of restricted marine occurrence. A position for the Chipola above the *Globigerinoides* datum (base of Zone N. 4) is dictated by the presence of this genus, and a maximum age reconcilable with Zone N. 5 is indicated by G. *subquadratus* and *Globigerinita glutinata,* both of which are unknown in sediments below this zone. A position below the *Orbulina* datum (top of Zone N. 8) is suggested by the absence of *Orbulina* spp. and other forms which are found in association with members of this long-ranging genus. Although it is a corollary of positive data, the absence of taxa is an unsatisfactory basis for biostratigraphic conclusions. In view of the number of Chipola samples examined, however, and confronted with the lack of more reliable criteria, a position below the evolutionary first occurrence of *Orbulina* must be accepted for the present. Thus, as Gibson (1967, p. 643) concluded, the Chipola appears to be correlative with the *Globigerinatella insueta* Zone of Trinidad (Zones N. 7 and N. 8), for which a Burdigalian age is assigned (Blow, 1969, fig. 19). Of these two zones, N. 7 is tentatively preferred for the Chipola Formation. This interpretation requires a greater age for the Chipola Formation and the *Globigerinatella insueta* Zone on the European time scale than earlier proposed by Akers and Drooger (1957, p. 658).

The Chipola has been correlated with beds in the valley of the Saucats, southwestern France, which contain *Miogypsina.* It is believed that this genus became extinct in the Gulf of Mexico region just prior to Chipola

time, since no specimens of *Miogypsina* have been found here in strata as young as either the Chipola Formation or the *Globigerinatella insueta* Zone of the Louisiana subsurface (Akers and Drooger, 1957, fig. 1). The Saucats also lies below the *Orbulina* datum, and an interesting analogy (but of dubious significance) is the dominance and large size attained by *Globigerinoides quadrilobatus quadrilobatus* in the writer's material from this European area. *Orbulina* first appears in Europe in beds considered to be Helvetian in age.

## ENCANTO FORMATION
Plates 6-9

Unnamed beds at TU 635 are referred provisionally here to the Encanto Formation (Harold E. and Emily H. Vokes, personal communication). The locality is a roadcut on the Trans-Isthmian Highway (Mexico Highway 185), 1.4 miles south of the bridge over Rio Jaltepec, Oaxaca, Mexico. Ages assigned to molluscan collections from this area have varied from lower Miocene to Pliocene (Durham, *et al.*, 1955, p. 985).

The foraminiferal fauna is interesting in that most of the benthonic components have been recorded from localities in northern Florida or the Louisiana subsurface Miocene. Among these are the following:

*Amphistegina lessonii* d'Orbigny
*Bolivina floridana* Cushman
*Bolivina marginata* Cushman
*Gyroidinoides scalata* (Garrett)
*Reussella miocenica* Cushman
*Siphogenerina lamellata* Cushman
*Uvigerina altacostata* Cushman and Ellisor
*Uvigerina peregrina* Cushman

The following planktonic foraminifera were identified from this locality:

*Biorbulina bilobata* (d'Orbigny)
*Globigerina* sp., pl. 6, fig. 1
*Globigerinoides obliquus obliquus* Bolli, pl. 7, fig. 1
*Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny), pl. 6, fig. 2
*Globoquadrina altispira globosa* Bolli, pl. 8, fig. 2
*Globoquadrina dehiscens* (Chapman, Parr, and Collins), pl. 8, fig. 1
*Globorotalia (Globorotalia) cultrata menardii* (Parker, Jones and Brady), pl. 9, fig. 2
*Globorotalia* sp., pl. 9, fig. 3
*Hastigerina (Hastigerina) siphonifera siphonifera* (d'Orbigny), pl. 9, fig. 1
*Orbulina suturalis* Bronnimann
*Orbulina universa* d'Orbigny
*Sphaeroidinellopsis subdehiscens subdehiscens* Blow, pl. 7, fig. 2

A single specimen was found (pl. 6, fig. 1) which bears a striking resemblance in rugose, mammillated wall structure to *Globigerapsis index* (Finlay), as illustrated by Blow (1969, pl. 27, figs. 1, 2). Rare, small specimens occur which seem to be referable to *Globorotalia (Globorotalia) paralenguaensis* Blow (pl. 9, fig. 3) for which a range is recorded from Zone N. 15 to Zone N. 16. A definite identification cannot be made because of a scarcity of specimens and the lack of topotypes for comparison. The species has been recorded only from the type locality, Muruan Formation, Papua.

Calcareous nannofossils are scarce in the Encanto Formation. Rare *Discoaster* cf. *D. deflandrei* Bramlette and Riedel and a single *Discoaster* cf. *D. hamatus* Martini and Bramlette were found.

The planktonic foraminiferal assemblage is dominated by *Globigerinoides obliquus obliquus, G. quadrilobatus quadrilobatus, Globoquadrina altispira globosa,* and *Globorotalia (G.) cultrata menardii. Globoquadrina dehiscens* and *Sphaeroidinellopsis subdehiscens subdehiscens* were rare but typical. All specimens of *Globorotalia (G.) cultrata menardii* are sinistrally coiled. Coiling in *Globoquadrina altispira globosa* is predominantly sinistral.

The oldest zone to which this planktonic assemblage can be assigned is Zone N. 13 on the basis of *Sphaeroidinellopsis subdehiscens subdehiscens*, which is not known to occur below this zone, and *Globorotalia (G.) cultrata menardii*, which is found as low as Zone N. 14 and questionably Zone N. 13 (Blow, 1969, p. 359). Zone N. 15 is the

highest *possible* position for the assemblage because of the absence of *Globigerinoides obliquus extremus* Bolli and Bermúdez, which appears in association with *G. obliquus obliquus* above Zone N. 15. The high frequency of the latter to the complete exclusion of the former is at least indicative of this interpretation though not conclusive because of the negative character of the data.

It is interesting, though again not a valid basis for exact age dtermination, that the benthonic fauna is identical with an association of species in the northern Gulf Coast which is invariably restricted to Zone N. 14 and the upper part of Zone N. 13.

## YELLOW RIVER FORMATION
Plates 10-13

The type locality for the *Yoldia* Zone of the Choctawhatchee Formation (Mansfield and Ponton, 1932) is on the Albert H. Cosson Farm (formerly Frazier's Farm), SE 1/4, Section 18, T2N, R19W, Walton County, Florida (Cushman and Ponton Sample No. 9, USGS locality No. 12060, 1932, pp. 13-14, 26-27). The Cosson Farm also is the type locality for the Yellow River Formation of Puri and Vernon (1964, pp. 200-202), who show a total of 7.5 feet exposed here representing the *Yoldia* Faunizone (Yellow River Formation), as follows:

| Bed | Description | Thickness (feet) |
|---|---|---|
| 2 | Greenish gray, sandy, plastic clay, casts of molluscs and scattered *Yoldia waltonensis* | 5.0 |
| 1 | Greenish gray shell marl with abundant *Yoldia waltonensis* | 2.5 |

Foraminifera are scarce in Bed 2, but at least 17 benthonic species and 12 planktonic forms occur in Bed 1. Cushman and Ponton (1932, table 1) list only two species of planktonic foraminifera from this locality, *Globorotalia menardii* (d'Orbigny) and *Orbulina universa* d'Orbigny, yet one of the richest planktonic assemblages to be found in the Middle Tertiary of northern Florida occurs here, both in terms of total specimens and in number of species per unit volume of formation material.

Planktonic foraminifera from the Yellow River Formation at the type locality, Bed 1, include:

*Biorbulina bilobata* (d'Orbigny)
*Globigerina juvenilis* Bolli, pl. 12, fig. 1
*Globigerinoides obliquus obliquus* Bolli, pl. 10, fig. 1
*Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny), pl. 11, figs. 2, 3
*Globoquadrina altispira globosa* Bolli, pl. 11, fig. 1
*Globorotalia (Globorotalia) cultrata menardii* (Parker, Jones and Brady), pl. 13, fig. 1
*Globorotalia (Turborotalia) minima* Akers, pl. 13, fig. 2
*Globorotalia (Turborotalia) siakensis* (LeRoy), pl. 13, fig. 3
*Hastigerina (Hastigerina) siphonifera siphonifera* (d'Orbigny), pl. 12, fig. 2
*Orbulina suturalis* Bronnimann
*Orbulina universa* d'Orbigny, pl. 10, fig. 2
*Sphaeroidinellopsis seminulina kochi* (Caudri), pl. 12, fig. 3

All of the species and subspecies listed here are abundant at the Cosson Farm site except *Globorotalia minima*, which, though not abundant, is typical (see Systematic Paleontology section for discussion of the morphology and range of this species). All specimens observed of *Globorotalia* and *Globoquadrina* were sinistrally coiled.

The following species of calcareous nannoplankton were identified from Bed 1 at the type locality. The first two species listed are the most abundant. Numerous coccoliths of *Cyclococcolithus* sp., probably *C. leptoporous* (Murray and Blackman), were also seen.

*Catinaster coalitus* Martini and Bramlette
*Discoaster brouweri* Tan Sin Hok
*Discoaster challengeri* Bramlette and Riedel
*Discoaster exilis* Martini and Bramlette
*Discoaster hamatus* Martini and Bramlette
*Discoaster variabilis* Martini and Bramlette
*Sphenolithus moriformis* (Bronnimann and Stradner)

The precise zone to which the Yellow River Formation (at the type locality) is referable is established by *Catinaster coalitus*. This nannofossil species is confined to a short interval within the middle Miocene of the Louisiana subsurface, some Lamont deep-sea cores, the experimental Mohole (Martini and Bramlette, 1963), and the *Globorotalia mayeri* Zone (as defined by Bolli, 1957; 1966) of the Cipero Formation, Trinidad (Bramlette and Wilcoxon, 1967, p. 108). The *Globorotalia mayeri* Zone of Bolli is Zone N. 14 of Blow (1969, fig. 15). It is also the highest zone in which *Globorotalia (T.) minima* and *Globorotalia (T.) siakensis* are found.

## RED BAY FORMATION ?
Plates 14-17

The type locality of the *Arca* Faunizone (Mansfield *in* Cooke and Mossom, 1929, pp. 140-142) is represented by 19 feet of gray, sandy and clayey, shell marl in the vicinity of Red Bay, Walton County, Florida. Puri and Vernon (1964, p. 197) designated the site here, now known as the W. D. McDaniel farm (Section 19, T2N, R17W), as the type locality for their Red Bay Formation. Cushman and Ponton (1932, table 1) list 40 species and varieties of benthonic foraminifera and one planktonic species (*Orbulina universa*) from these beds. Investigations by the writer, however, have failed to reveal the foraminiferal fauna reported here by Cushman and Ponton and as attirbuted to these authors by Puri and Vernon (1964, pp. 198-199). Only rare specimens of *Amphistegina lessonii* can be found at this locality. It is the writer's opinion that the locality records of Cushman and Ponton are in error, and that the benthonic foraminifera attributed to the McDaniel farm were in actuality derived from the Blount's Creek site (Section 27, T2N, R19W). Benthonic species obtained by the writer from the Blount's Creek locality match the list for the McDaniel farm site.

USGS locality No. 12046, Sample No. 8 of Cushman and Ponton (1932, pp. 13, 26-27), is from 100 feet below a small falls near head of Vaughan Creek (locally known as Blount's Creek), Section 27, T2N, R19W, Walton County, Florida. Cushman and Ponton (1932, p. 13) place six feet of marl at this locality in the lower part of the *Arca* Zone of the Choctawhatchee Formation and refer to the molluscan fauna as "especially well preserved and numerous as to species." They list 48 species and varieties of benthonic foraminifera but only a single planktonic species, *Orbulina universa* d'Orbigny.

Beds at the Blount's Creek locality are assigned provisionally to the Red Bay Formation on the assumption that they have been placed correctly in the *Arca* Faunizone. There is no microfaunal basis for correlating the section at Red Bay with beds at the Blount's Creek locality.

The following plantonic foraminifera have been identified at the Blount's Creek site:

*Biorbulina bilobata* (d'Orbigny)
*Globigerina bulloides bulloides* d'Orbigny, pl. 14, fig. 4
*Globigerina* cf. *G. druryi decoraperta* Takayanagi and Saito, pl. 14, fig. 3
*Globigerina juvenilis* Bolli
*Globigerina nepenthes* Todd, pl. 14, fig. 1
*Globigerinita uvula* (Ehrenberg), pl. 15, fig. 2
*Globigerinoides bollii* Blow
*Globigerinoides obliquus extremus* Bolli and Bermúdez
*Globigerinoides obliquus obliquus* Bolli, pl. 16, fig. 1
*Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny), pl. 16, fig. 4
*Globigerinoides ruber* (d'Orbigny), pl. 16, fig. 3
*Globigerinoides* sp., pl. 16, fig. 2
*Globoquadrina altispira globosa* Bolli, pl. 15, fig. 1
*Globoquadrina dehiscens* (Chapman, Parr, and Collins), pl. 15, fig. 3
*Globorotalia (Turborotalia) acostaensis acostaensis* Blow, pl. 17, fig. 1
*Globorotalia (Turborotalia) acostaensis humerosa* Takayanagi and Saito, pl. 17, fig. 4
*Globorotalia (Globorotalia) cultrata menardii* (Parker, Jones and Brady), pl. 17, fig. 2

*Hastigerina (Hastigerina) siphonifera siphonifera* (d'Orbigny), pl. 17, fig. 3
*Orbulina suturalis* Bronnimann
*Orbulina universa* d'Orbigny
*Sphaeroidinellopsis seminulina seminulina* (Schwager), pl. 14, fig. 2
*Sphaeroidinellopsis subdehiscens subdehiscens* Blow

The predominant planktonic forms at Blount's Creek are *Globigerinoides quadrilobatus quadrilobatus* and *Globigerinoides obliquus obliquus*. *Globorotalia (T.) acostaensis acostaensis* and *Globorotalia (G.) cultrata menardii* are scarce but typical. Only four specimens of each were found at this locality. All four specimens of the latter are sinistrally coiled. *Globigerina nepenthes* is rare, and none of the specimens have the final thumb-like chamber seen in adult forms when they occur in high frequency.

Typical *Globigerinoides ruber* is rare, and specimens occur in this assemblage that appear transitional between this species and *Globigerinoides bollii*. Blow (1969) has reported that the development of *G. ruber* from *G. bollii* occurs in Zone N. 16. All of the specimens of *Globigerina bulloides bulloides* bear a resemblance to *Globigerina praebulloides praebulloides* Blow, suggesting that the beds at Blount's Creek represent a time close to the divergence of these taxa, which may have taken place within the later half of Zone N. 16 (Blow, 1969). Specimens of *Globorotalia (T.) acostaensis humerosa* appear to be rather primitive forms, all having fewer chambers than observed in higher zones.

Several specimens of *Globigerinoides* (pl. 16, fig. 2) were found which may be aberrant forms of *G. quadrilobatus quadrilobatus*, although there seems to be a difference in wall structure. A few specimens are referred provisionally to *Globigerina druryi decoraperta*. Forms from the Blount's Creek locality have a larger and more weakly lipped aperture than usually seen in that taxon. The Blount's Creek specimens are also larger than typical in that subspecies.

The following species of calcareous nannoplankton were identified at the Blount's Creek locality:

*Discoaster exilis* Martini and Bramlette
*Discoaster hamatus* Martini and Bramlette
*Discoaster pentaradiatus* Tan Sin Hok
*Discoaster variabilis* Martini and Bramlette
*Braarudosphaera bigelowi* (Gran and Braarud) Deflandre
*Lithostromation perdurum* Deflandre

All of the above data and in particular the occurrence of early phylogenetic forms of *Globigerina bulloides bulloides*, *Globigerinoides ruber*, and *Globorotalia (T.) acostaensis humerosa* suggest a position in Zone N. 17 for the beds at Blount's Creek.

## JACKSON BLUFF FORMATION
## ECPHORA FAUNIZONE
### Alum Bluff, Bed 4
### Plates 18-20

This locality is on the east side of the Apalachicola River, about four miles north of Bristol, Liberty County, Florida, in the SW 1/4, SE 1/4, NE 1/4, Section 24, T1N, R8W. Sample No. 12, USGS locality numbers 1/670 and 1/956 of Cushman and Ponton (1932, p. 14) is from this site.

Bed 4 of the section at this locality (Puri and Vernon, 1964, pp. 202-204) is the *Ecphora* "bed" of Dall (1892) and represents the *Ecphora* Zone of Mansfield (*in* Cooke and Mossom, 1929). This is the type locality for the *Ecphora* Faunizone, and both Bed 4 and Bed 5 of the section at this locality are assigned by Puri and Vernon (1964, p. 202) to their Jackson Bluff Formation. Puri and Vernon (1964, p. 204) describe the lithology of Bed 4 as a very sandy, blue and bluish gray shell marl, practically a coquina. The upper six inches is glauconitic and indurated, and the lower foot contains pebbles of gray, phosphoritic, sandy limestone, gray sandstone, and blue clay. They give 13.5 feet for the thickness of this bed. Mollusk shells are abundant, although *Ecphora quadricostata* var. *umbilicata*, for which the faunizone was named, is rare. Cushman and Ponton (1932) recorded 43 species and varieties of benthonic foraminifera from Bed 4 but only *Orbulina universa* and *Globorotalia menardii* among the planktonics.

The following planktonic foraminifera were found in Bed 4 at the Alum Bluff site:

*Globigerina bulloides apertura* Cushman, pl. 19, fig. 1
*Globigerina bulloides bulloides* d'Orbigny
*Globigerina druryi decoraperta* Takayanagi and Saito
*Globigerina juvenilis* Bolli, pl. 19, fig. 5
*Globigerinoides bollii* Blow
*Globigerinoides obliquus obliquus* Bolli, pl. 18, fig. 2
*Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny), pl. 18, fig. 1
*Globigerinoides ruber* (d'Orbigny), pl. 18, fig. 3
*Globoquadrina altispira globosa* Bolli, pl. 20, fig. 1
*Globorotalia (Turborotalia) acostaensis humerosa* Takayanagi and Saito, pl. 19, fig. 3
*Globorotalia (Globorotalia) cultrata menardii* (Parker, Jones, and Brady)
*Globorotalia (Globorotalia) margaritae* Bolli and Bermúdez, pl. 19, fig. 4
*Globorotalia (Globorotalia) multicamerata* Cushman and Jarvis, pl. 19, fig. 2
*Globorotaloides hexagona hexagona* (Natland)
*Orbulina universa* d'Orbigny
*Sphaeroidinellopsis subdehiscens subdehiscens* Blow, pl. 20, figs. 2-4

Some of the most significant species are of low frequency in this assemblage. Only five specimens of *Globorotaloides hexagona hexagona* were found. These are typical, however, and fix the maximum possible age of Bed 4 within Zone N. 18. *Globorotalia (G.) margaritae,* of which only three juvenile specimens (all sinistrally coiled) were observed, ranges from the middle to later parts of Zone N. 16 to within Zone N. 19 (Blow, 1969). *Globorotalia (G.) cultrata menardii* is rare and dextrally coiled. In the Atlantic regions, including the Gulf of Mexico and Caribbean, predominantly dextral specimens of this taxon indicate an age of Pliocene or latest Miocene. *Globorotalia (G.) multicamerata,* also rare and typically dextral, ranges from the middle of Zone N. 17 to Zone N. 21.

Among the calcareous nannoplankton, the following species occur in Bed 4:

*Discoaster pentaradiatus* Tan Sin Hok
*Discoaster perplexus* Bramlette and Riedel
*Discoaster surculus* Martini and Bramlette
*Discoaster variabilis* Martini and Bramlette
*Lithostromation perdurum* Deflandre

Biostratigraphically, *Discoaster surculus* is the most significant member of this nannofossil assemblage, since it has the most restricted range in time. All of the other species are known from strata of Miocene, as well as Pliocene age. It is noteworthy that this form does not occur in the youngest Miocene (Zone N. 15) of Trinidad (Bramlette and Wilcoxon, 1967). It does occur in the subsurface Pliocene of the Gulf of Mexico region, however, making its first appearance near the Miocene-Pliocene boundary. Martini and Bramlette (1963) logged the species in the experimental Mohole only in the section attributed by them to the Pliocene. Hay and Schmidt (1968) report *Discoaster surculus* from the Plaisancian section at Castell-'Arquato and from the Trubi Marl of Cattolica Eraclea, Sicily, which is considered to be early Pliocene (from the middle of Zone N. 18 to the top of Zone N. 19 of Blow, 1969). Hay and Boudreaux (1968, p. 145) report the species in the 200 cm core of the Submarex boring, Nicaragua Rise, Caribbean Sea, and term it "a typical Pliocene form."

Both the nannofossil and the foraminiferal data, therefore, point to an age for Bed 4 at Alum Bluff of early Pliocene (middle of Zone N. 18 to within Zone N. 19). Hazel (1971, p. 8) suggested that the *Ecphora* Zone should be assigned to N. 18 or N. 19 on the basis of the planktonic foraminifera identified by Ruth Todd from bed 4 of Puri and Vernon (1964, p. 204) at Alum Bluff.

## JACKSON BLUFF FORMATION ?
## ECPHORA FAUNIZONE
### Watson's Landing
### Plates 21-25

This site is a cut in the road leading to Watson's Landing, about two miles north of Alum Bluff and about two miles from the

Apalachicola River, 2000 feet north and 100 feet west of the southeast corner of Section 7, T1N, R7W, Liberty County, Florida. The locality is represented by outcrop sample no. 46 of Puri (1953, p. 60), who termed the section here "*Ecphora* Facies of the Choctawhatchee Stage."

Beds about 40 feet above the river terrace were identified with the *Ecphora* Zone of the Chocatwhatchee Formation by Cushman and Ponton (1932, p. 18), who recorded 13 species and varieties of benthonic foraminifera but no planktonics. The writer collected material from a tan to brown colored shell bed above a white to buff marl in 1957. Well preserved mollusks were abundant.

The following planktonic foraminifera are present at this locality:

*Globigerina bulloides apertura* Cushman, pl. 21, fig. 3
*Globigerina bulloides bulloides* d'Orbigny
*Globigerina druryi decoraperta* Takayanagi and Saito
*Globigerina juvenilis* Bolli
*Globigerina* sp., pl. 21, fig. 1
*Globigerinita glutinata* (Egger), pl. 21, fig. 2
*Globigerinoides bollii* Blow, pl. 22, fig. 2
*Globigerinoides conglobatus conglobatus* (Brady), pl. 24, figs. 1, 2
*Globigerinoides obliquus extremus* Bolli and Bermúdez, pl. 23, fig. 2
*Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny), pl. 22, fig. 1
*Globigerinoides ruber* (d'Orbigny), pl. 22, fig. 3; pl. 23, fig. 1
*Globoquadrina altispira globosa* Bolli, pl. 25, fig. 1
*Globoquadrina conglomerata* (Schwager)
*Globorotalia (Turborotalia) acostaensis humerosa* Takayanagi and Saito, pl. 25, fig. 2
*Globorotalia (Globorotalia) miocenica* Palmer
*Globorotalia (Turborotalia) scitula scitula* (Brady)
*Globorotaloides hexagona hexagona* (Natland)
*Hastigerina (Hastigerina) siphonifera siphonifera* (d'Orbigny), pl. 24, fig. 3
*Orbulina universa* d'Orbigny
*Sphaeroidinella dehiscens dehiscens* forma *immatura* (Cushman)
*Sphaeroidinellopsis subdehiscens subdehiscens* Blow
*Turborotalita quinqueloba* (Natland)

Most of the foraminifera listed above can be found at Watson's Landing with diligent searching. Only four specimens of *Globigerinoides conglobatus conglobatus* and *Orbulina universa* were seen. Two specimens each of *Sphaeroidinella dehiscens dehiscens* forma *immatura* and *Globorotalia (T.) scitula scitula* and six specimens of *Globorotaloides hexagona hexagona* were found.

The following species of calcareous nannoplankton were identified at Watson's Landing:

*Discoaster brouweri* Tan Sin Hok (both five and six rayed forms)
*Discoaster pentaradiatus* Tan Sin Hok
*Discoaster surculus* Martini and Bramlette
*Lithostromation perdurum* Deflandre
*Sphenolithus abies* Deflandre

Planktonic microfossil assemblages at Alum Bluff, Bed 4, and Watson's Landing are similar in constituents. It is possible that the beds at Watson's Landing are slightly younger, since *Globoquadrina conglomerata* occurs there and has not been found in Bed 4, Alum Bluff. This species has not been documented below the later parts of Zone N. 19. *Sphaeroidinella dehiscens dehiscens* forma *immatura* was also found at Watson's Landing but not at Alum Bluff, Bed 4. It is confined to Zone N. 19, according to Blow (1969).

## JACKSON BLUFF FORMATION ?
## ECPHORA FAUNIZONE ?
### Darling Slide
### Plates 26-33

This site (TU 712) is an old log slide at a bluff on the east bank of the Chipola River, about 2.5 miles southeast of Clarksville, Calhoun County, Florida. It is USGS locality no. 1/960 of Cushman (1930, p. 13) and Cushman and Ponton (1932, p. 17). Collec-

tions were made here by the writer in November, 1957, from two horizons, one near the base of the exposure, and one, seven feet higher.

According to Cushman and Ponton (1932, p. 17), the molluscan fauna is poorly preserved and small as to species. *Mulinia congesta* is abundant. They recorded 36 species and varieties of benthonic foraminifera but only three planktonic species, *Hastigerina pelagica (Hastigerina (H.) siphonifera siphonifera), Orbulina universa,* and *Globorotalia menardii* (*Globorotalia cultrata* subspecies). These authors relate this locality to the *Ecphora* Zone, Choctawhatchee Formation.

The following planktonic foraminifera were identified at Darling Slide:

*Globigerina bulloides apertura* Cushman, pl. 30, fig. 1; pl. 31, fig. 1
*Globigerina bulloides bulloides* d'Orbigny, pl. 30, fig. 2; pl. 31, fig. 2
*Globigerina druryi decoraperta* Takayanagi and Saito, pl. 29, fig. 1; pl. 31, fig. 3
*Globigerina juvenilis* Bolli
*Globigerina* sp., pl. 29, fig. 2
*Globigerinita glutinata* (Egger), pl. 33, fig. 3
*Globigerinita uvula* (Ehrenberg), pl. 29, fig. 3
*Globigerinoides obliquus obliquus* Bolli, pl. 26, fig. 2; pl. 27, fig. 3
*Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny), pl. 27, fig. 2; pl. 30, fig. 3
*Globigerinoides ruber* (d'Orbigny), pl. 26, fig. 4; pl. 27, fig. 1
*Globoquadrina conglomerata* (Schwager)
*Globorotalia (Turborotalia) acostaensis humerosa* Takayanagi and Saito, pl. 26, fig. 3; pl. 28, fig. 2
*Globorotalia (Globorotalia) cultrata limbata* (Fornasini), pl. 33, fig. 2
*Globorotalia (Globorotalia) cultrata* subspecies, pl. 32, fig. 2
*Globorotalia (Globorotalia) margaritae* Bolli and Bermúdez, pl. 32, fig. 1; pl. 33, fig. 1
*Globorotalia (Turborotalia) praeoscitans,* new species, pl. 32, fig. 3
*Globorotaloides hexagona hexagona* (Natland), pl. 28, fig. 1
*Hastigerina (Hastigerina) siphonifera siphonifera* (d'Orbigny), pl. 26, fig. 1; pl. 31, fig. 4
*Turborotalita quinqueloba* (Natland)

A species of *Globigerina* (pl. 29, fig. 2) resembles the form from Watson's Landing (pl. 21, fig. 1). These may be related to *Globigerina juvenilis*. The specimens of *Globorotalia (G.) margaritae* are not as large as most specimens from deep-sea cores, nor do they have the extremely arched spiral side characteristic of specimens from predominantly planktonic assemblages. The Florida form may be a subspecies of this group. The predominantly dextral coiling of the *Globorotalia (G.) cultrata* complex and the predominantly sinistral coiling of associated *Globorotalia (G.) margaritae* in the *Ecphora* Faunizone present an interesting analogy with the occurrence of these taxa in Java and the Caribbean area. "In all samples studied from these areas, the new species *(G. margaritae)* coils sinistrally, whereas *Globorotalia menardii* strongly prefers dextral coiling in the same samples" (Bolli and Bermúdez, 1965, p. 140). The samples described by Bolli and Bermudez are now considered lower Pliocene by Blow (1969), that is, the later part of Zone N. 18 and at least the early part of Zone N. 19.

Microfossil assemblages from the two horizons sampled at Darling Slide were examined separately and are illustrated separately here. There are no significant differences, however, either quantitatively or qualitatively, between the planktonic assemblages of the two beds.

The following species of calcareous nannofossils are present in both of the samples taken at Darling Slide:

*Discoaster brouweri* Tan Sin Hok
*Discoaster pentaradiatus* Tan Sin Hok
*Braarudosphaera bigelowi* (Gran and Braarud) Deflandre
*Lithostromation perdurum* Deflandre

A single specimen of *Discoaster variabilis* Martini and Bramlette was observed from the upper horizon.

Coccoliths are abundant in the material from Darling Slide, and it is a paradox that *Sphenolithus abies* Deflandre was not seen, since it almost invariably occurs in lower Pliocene sediments of the Gulf of Mexico region in which coccoliths are so highly concentrated as at this locality. The absence of this species in such sediments usually indicates an age younger than early Pliocene (Gartner, 1969, fig. 7). There is nothing in either the foraminiferal assemblages or the calcareous nannoplankton concentrations, however, which would confirm an age for these beds younger than those at Watson's Landing. *Globoquadrina conglomerata,* though rare, indicates that the Darling Slide beds are no older than Zone N. 19. It must be concluded, on the basis of planktonic microfossils, that the early investigators were correct in referring these sediments to the same faunizone as the strata at Watson's Landing and Bed 4 of Alum Bluff.

JACKSON BLUFF FORMATION
ECPHORA FAUNIZONE
Jackson Bluff, Bed 9
Plates 34-46

This locality is on the left bank of the Ocklocknee River, just above the bridge, Leon County, Florida. It is the horizon for Sample no. 37, USGS locality no. 1/967 of Cushman (1930, p. 13) and Cushman and Ponton (1932, p. 17). It is also Stop 55, Bed 9, of Puri and Vernon (1964, p. 208).

The assemblage here represents the latest fauna of the *Ecphora* Zone of the Choctawhatchee Formation according to Cushman and Ponton (1932, p. 17). Puri and Vernon (1964, p. 208) consider Bed 9 as the upper bed of the *Ecphora* Faunizone of their Jackson Bluff Formation, Choctawhatchee Stage. They describe it as 2 feet of "shell marls, with abundant *Pecten* in a bluish gray clay matrix."

The writer sampled this bed in May, 1956, and found it to be slightly glauconitic. Cushman and Ponton (1932, Table 1) listed 17 species and varieties of benthonic foraminifera from the zone. They made no mention of planktonic forms.

The following planktonic foraminifera occur in Bed 9, Jackson Bluff:

*Globigerina bulloides bulloides* d'Orbigny, pl. 34, fig. 1
*Globigerina druryi decoraperta* Takayanagi and Saito, pl. 34, fig. 3
*Globigerina juvenilis* Bolli
*Globigerinoides bollii* Blow
*Globigerinoides obliquus extremus* Bolli and Bermúdez
*Globigerinoides obliquus obliquus* Bolli, pl. 35, fig. 1
*Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny), pl. 34, fig. 4

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PLATE 1
CHIPOLA FORMATION
TU 951

Figures Page

1. *Cassigerinella chipolensis* (Cushman and Ponton). . . . . 130
Maximum diameter, 0.23 mm
   a. Side view, showing aperture, X 280
   b. Opposite side, X 280
   c. Portion of penultimate chamber in fig. 1a, X 560
   d. Portion of penultimate chamber in fig. 1a, X 1120

2. *Globigerinita uvula* (Ehrenberg). . . . . 72
Maximum diameter, 0.23 mm
   a. Apertural view, X 280
   b. Opposite side, X 280

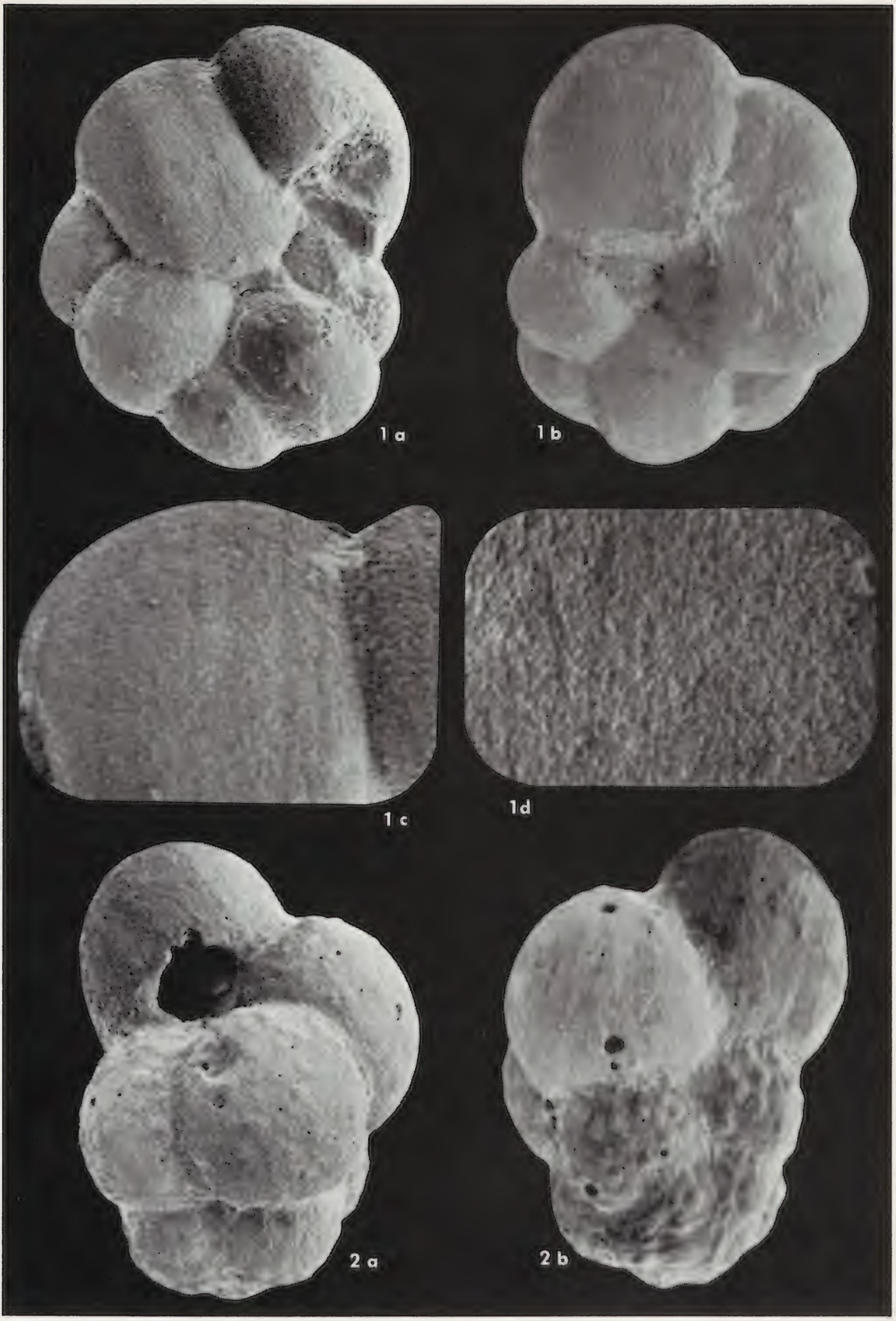


Plate 1

*Globigerinoides ruber* (d'Orbigny), pl. 35, fig. 2
*Globorotalia (Turborotalia) acostaensis humerosa* Takayanagi and Saito, pl. 36, fig. 2
*Globorotalia (Globorotalia) cultrata* subspecies, pl. 36, fig. 1
*Globorotalia (Turborotalia) praeoscitans,* new species, pl. 36, fig. 3
*Orbulina universa* d'Orbigny
*Sphaeroidinellopsis subdehiscens subdehiscens* Blow, pl. 34, fig. 2; pl. 35, figs. 3, 4

Except that planktonic specimens are scarcer, this is a similar assemblage to those at Darling Slide, Watson's Landing, and Alum Bluff, Bed 4. A dextrally coiled subspecies of *Globorotalia (G.) cultrata* (pl. 36, fig. 1) occurs here, which is close in appearance to that at Darling Slide (pl. 32, fig. 2). A single specimen of *Globorotalia (T.) praeoscitans,* n. sp., was found which appears to be the same form seen at Darling Slide (pl. 32, fig. 3), where it is also rare. Planktonic foraminifera are rare in Bed 9, Jackson Bluff. *Globigerinoides ruber* and *Globigerinoides obliquus obliquus* are the most frequent taxa in the assemblage.

Calcareous nannofossils are rare, there being only an average of 10 specimens per 20 mm at X600. No discoasters were observed, nor were *Sphenolithus* or *Lithostromation.*

This bed is tentatively assigned to the upper part of Zone N. 18 to the upper part of Zone N. 19 on the similarity of the planktonic foraminiferal assemblage here and at Darling Slide, Watson's Landing, and Alum Bluff, Bed 4. A precise assignment within the Pliocene is not as apparent for Jackson Bluff, Bed 9, as for the strata at these other sites.

## JACKSON BLUFF FORMATION
## CANCELLARIA FAUNIZONE
### Jackson Bluff, Bed 10
### Plates 37-40

This locality is on the left bank of the Ocklocknee River, just above the bridge, Leon County, Florida. It is the horizon for Sample no. 14, USGS locality no. 11732 of Cushman and Ponton (1932, p. 14), who described the locality as a borrow-pit just east of the power dam at Jackson Bluff, Florida. It is also Stop 55, Bed 10, of Puri and Vernon (1964, p. 208).

This bed is four feet thick and is a "cream to white, sandy shell marl, and sand with abundant mollusks" according to Puri and Vernon (1964, p. 208), who designated it as the *Cancellaria* Faunizone of their Jackson Bluff Formation, Choctawhatchee Stage.

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## PLATE 2
## CHIPOLA FORMATION
### TU 820

Figures Page

1. *Cassigerinella chipolensis* (Cushman and Ponton). . . . . 130
Maximum diameter, 0.17 mm

a. Side view (showing aperture), X 406
b. View of wall of penultimate chamber shown in fig. 1a, X 7350
c. View of penultimate chamber shown in fig. 1a, X 700
d. View of wall of penultimate chamber shown in fig. 1a, X 3500

### TU 951

2. *Globigerinoides* sp., a rare form which resembles *Globigerinoides sicanus* de Stefani. This is probably an aberrant *Globigerinoides quadrilobatus quadrilobatus.* . . . 10
Maximum diameter, 0.48 mm

a. Side view, X 98
b. Opposite view, X 100

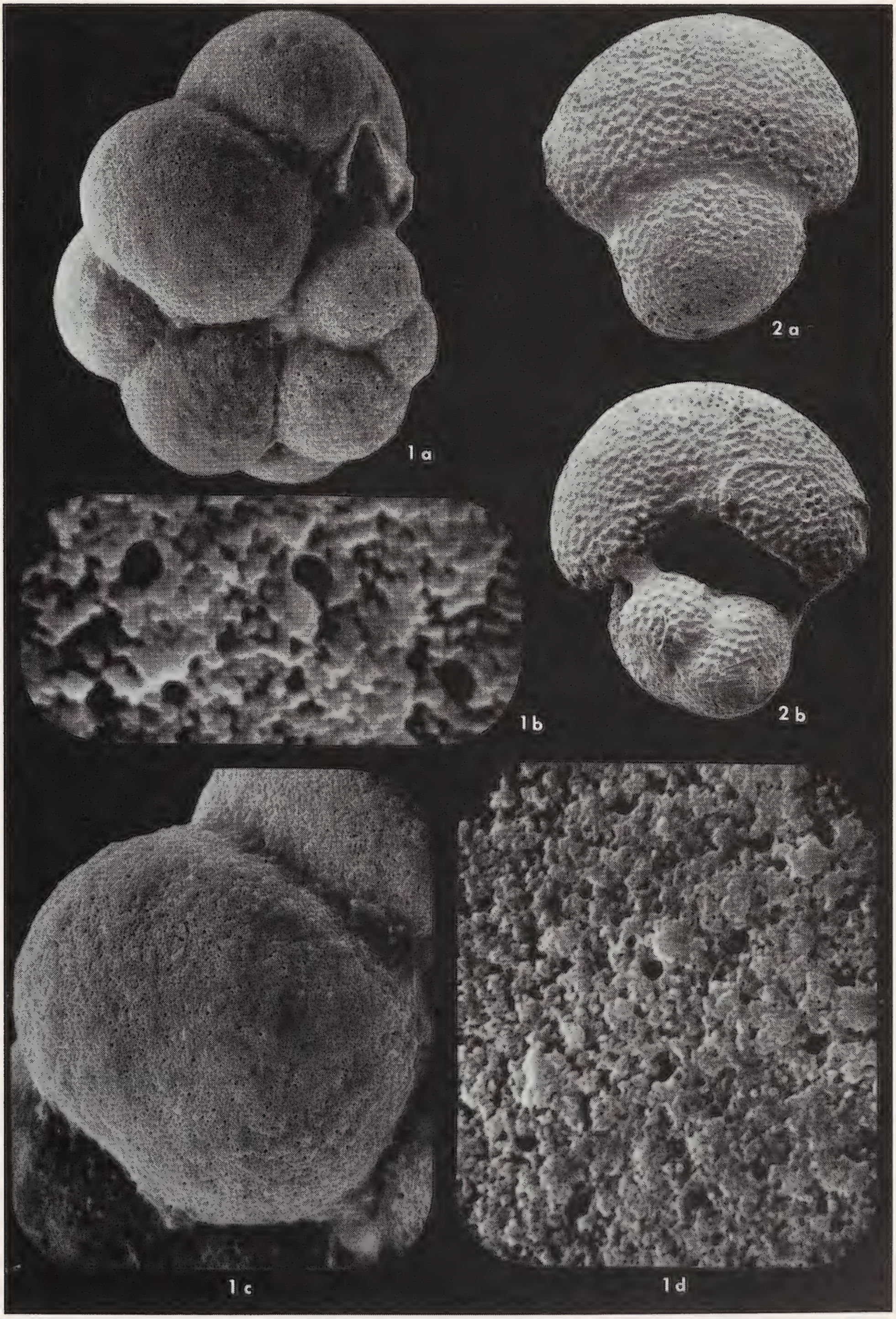


Plate 2

Cushman and Ponton (1932, p. 14) considered the bed representative of the *Cancellaria* Zone of the Choctawhatchee Formation. They reported (Table 1) 49 species and varieties of benthonic foraminifera and a single planktonic form, *Orbulina universa* d'Orbigny.

The writer has identified the following planktonic foraminifera from this bed:

*Globigerina bulloides apertura* Cushman, pl. 37, fig. 1
*Globigerina bulloides bulloides* d'Orbigny, pl. 37, fig. 3
*Globigerina druryi decoraperta* Takayanagi and Saito, pl. 37, fig. 2
*Globigerina juvenilis* Bolli
*Globigerinita glutinata* (Egger), pl. 38, fig. 2
*Globigerinoides bollii* Blow
*Globigerinoides obliquus extremus* Bolli and Bermúdez, pl. 38, fig. 1
*Globigerinoides obliquus obliquus* Bolli
*Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny), pl. 39, fig. 2
*Globigerinoides ruber* (d'Orbigny), pl. 38, fig. 3
*Globoquadrina altispira globosa* Bolli, pl. 40, fig. 1
*Globorotalia (Turborotalia) acostaensis humerosa* Takayanagi and Saito, pl. 40, fig. 2
*Globorotalia (Globorotalia) cultrata* subspecies, pl. 40, fig. 3
*Hastigerina (Hastigerina) siphonifera siphonifera* (d'Orbigny)
*Orbulina suturalis* Bronnimann
*Orbulina universa* d'Orbigny
*Sphaeroidinellopsis subdehiscens subdehiscens* Blow, pl. 39, fig. 1, 3

Planktonic foraminifera are more abundant in this upper bed than in the lower Bed 9. *Globigerinoides ruber* is the most

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PLATE 3
CHIPOLA FORMATION
TU 951

Figures Page

1. *Globorotalia (Turborotalia) obesa* Bolli. . . . . 116
Maximum diameter, 0.69 mm
a. Umbilical view, X 140
b. Spiral view, X 99
c. Edge view, X 140

2. *Globigerinoides* sp., a form resembling *Globigerinoides quadrilobatus altiaperturus* Bolli, but having apertures wider than in that subspecies. . . . . 10
Maximum diameter, 0.44 mm
a. Spiral view, X 132
b. Umbilical view, X 131

3. *Globoquadrina baroemoenensis* (LeRoy). . . . . 90
Maximum diameter, 0.47 mm
a. Spiral view, X 100
b. Umbilical view, X 100

4. *Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny). . . . . 62
Maximum diameter, 0.63 mm
a. Umbilical view, X 99
b. Spiral view, X 91

Plate 3

frequently encountered species. Of the above taxa, only members of *Globoquadrina, Globorotalia,* and *Hastigerina* are rare in samples from this horizon. All of the few *Globorotalia cultrata* forms seen were dextrally coiled.

Calcareous nannofossils are also far more abundant in Bed 10 than in Bed 9, but discoasters are slightly calcified. No bifurcating forms were seen, and *Discoaster brouweri* was the only species of this genus positively identified. Two to five specimens per 20 mm were observed at X600. Other species identified were *Lithostromation perdurum, Braarudosphaera bigelowi,* and *Coccolithus pelagicus.*

No basis was seen among the microfossils at Jackson Bluff for an assignment of Bed 10 to a younger zone than that of the *Ecphora* beds (Zone N. 19).

## JACKSON BLUFF FORMATION ?
## CANCELLARIA FAUNIZONE ?
### R. L. Gainer Farm
### Plates 41-46

This site on the Econfina River in Section 4, T1S, R13W, Bay County, Florida, is Sample no. 36, USGS locality no. 1/953 of Cushman (1930, p. 13) and Cushman and Ponton (1932, p. 17). The locality was sampled by the writer in November, 1957, when it appeared, as described by Cushman and Ponton (1932, p. 17), to be "loose shells representing the *Cancellaria* Zone of the Choctawhatchee Formation . . . lying on the hard indurated Chipola Formation . . . " Although they reported that "no exposure of the marl was seen in place," the writer's material is believed to be in place, representing the near horizontal surface of the exposure. It is uncontaminated by Chipola microfossils.

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## PLATE 4
## CHIPOLA FORMATION
## TU 951

Figures

Page

1. *Globigerinoides* sp. . . . . 10
Maximum diameter, 0.59 mm
   a. Umbilical view, X 99
   b. Spiral view, X 98

2. *Globigerinoides* sp. . . . . 10
Maximum diameter, 0.53 mm
   a. Spiral view, X 99
   b. Umbilical view, X 98

3. *Globigerinoides subquadratus* Bronnimann. . . . . 68
Maximum diameter, 0.59 mm
   a. Spiral view, X 101
   b. Umbilical view, X 101

4. *Globigerinoides* sp. . . . . 10
Maximum diameter, 0.68 mm
   a. Spiral view, X 99
   b. Umbilical view, X 99

1, 2, and 4 are possible variants of *Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny). These seem to be transitional forms between the typical and rare specimens (fig. 2, 4). The latter may be gerontic.

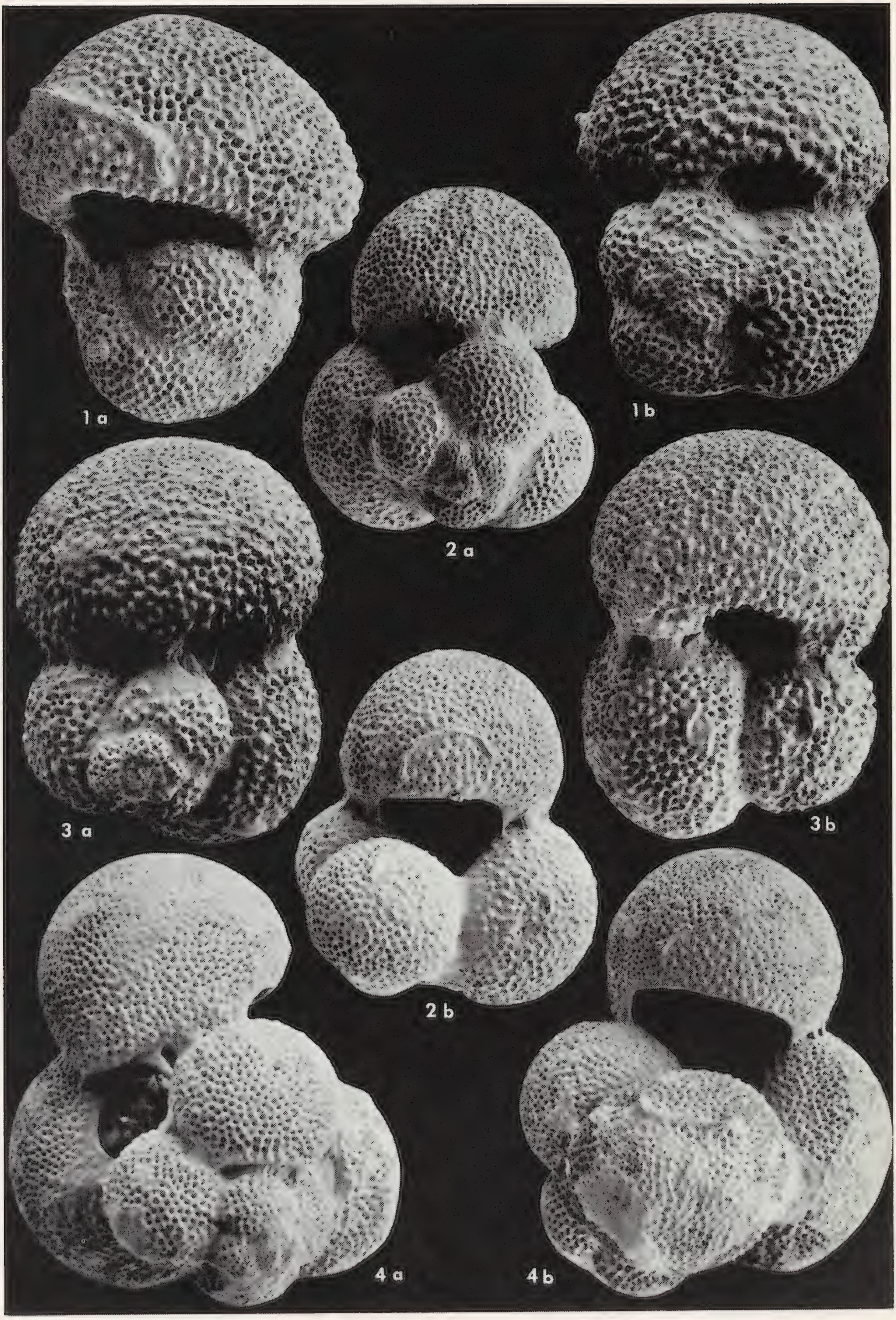


Plate 4

The above authors identified only 11 species and varieties of benthonic foraminifera from this locality, and they made no mention of planktonic forms.

The present investigation has disclosed the following planktonic foraminifera at the Gainer locality:

*Globigerina bulloides apertura* Cushman, pl. 42, fig. 1
*Globigerina bulloides bulloides* d'Orbigny, pl. 41, fig. 1
*Globigerina druryi decoraperta* Takayanagi and Saito
*Globigerina juvenilis* Bolli
*Globigerinoides obliquus extremus* Bolli and Bermúdez, pl. 43, fig. 1
*Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny), pl. 42, fig. 2
*Globigerinoides ruber* (d'Orbigny), pl. 43, fig. 2
*Globoquadrina altispira altispira* (Cushman and Jarvis), pl. 44, fig. 1
*Globoquadrina altispira globosa* Bolli
*Globorotalia (Turborotalia) acostaensis humerosa* Takayanagi and Saito, pl. 44, fig. 2
*Globorotalia (Globorotalia) cultrata* subspecies, pl. 46, fig. 2
*Globorotalia (Globorotalia) multicamerata* Cushman and Jarvis, pl. 46, fig. 1
*Globorotaloides hexagona hexagona* (Natland)
*Hastigerina (Hastigerina) siphonifera siphonifera* (d'Orbigny), pl. 46, fig. 3
*Orbulina universa* d'Orbigny
*Sphaeroidinella dehiscens dehiscens* (Parker and Jones), pl. 45, fig. 2
*Turborotalita quinqueloba* (Natland), pl. 41, fig. 2; pl. 45, fig. 1

The predominant planktonic forms in the Gainer beds are *Globigerinoides ruber* and *Globigerinoides quadrilobatus quadrilobatus. Orbulina universa* and *Sphaeroidinella dehiscens dehiscens* are rare. The other forms listed above can be found in sufficient numbers with diligent searching to illustrate the range of variation for the various taxa.

Coiling in the complex of *Globorotalia cultrata* subspecies and *Globorotalia multicamerata* is predominantly dextral. The most significant foraminifera at this locality are *Sphaeroidinella dehiscens dehiscens,* which is known from the base of Zone N. 19 (Blow,

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PLATE 5
CHIPOLA FORMATION
TU 951

Figures Page

1. *Globorotalia (Turborotalia) siakensis* (LeRoy). . . . . 122
Maximum diameter, 0.45 mm
a. Umbilical view, X 140
b. Edge view, X 136
c. Spiral view, X 140

2. *Globoquadrina baroemoenensis* (LeRoy). . . . . 90
Maximum diameter, 0.48 mm
a. Umbilical view, X 112
b. Spiral view, X 112

TU 820-B

3. *Globoquadrina baroemoenensis* (LeRoy). . . . . 90
Maximum diameter, 9.53 mm
a. Spiral view, X 136
b. Umbilical view, X 136

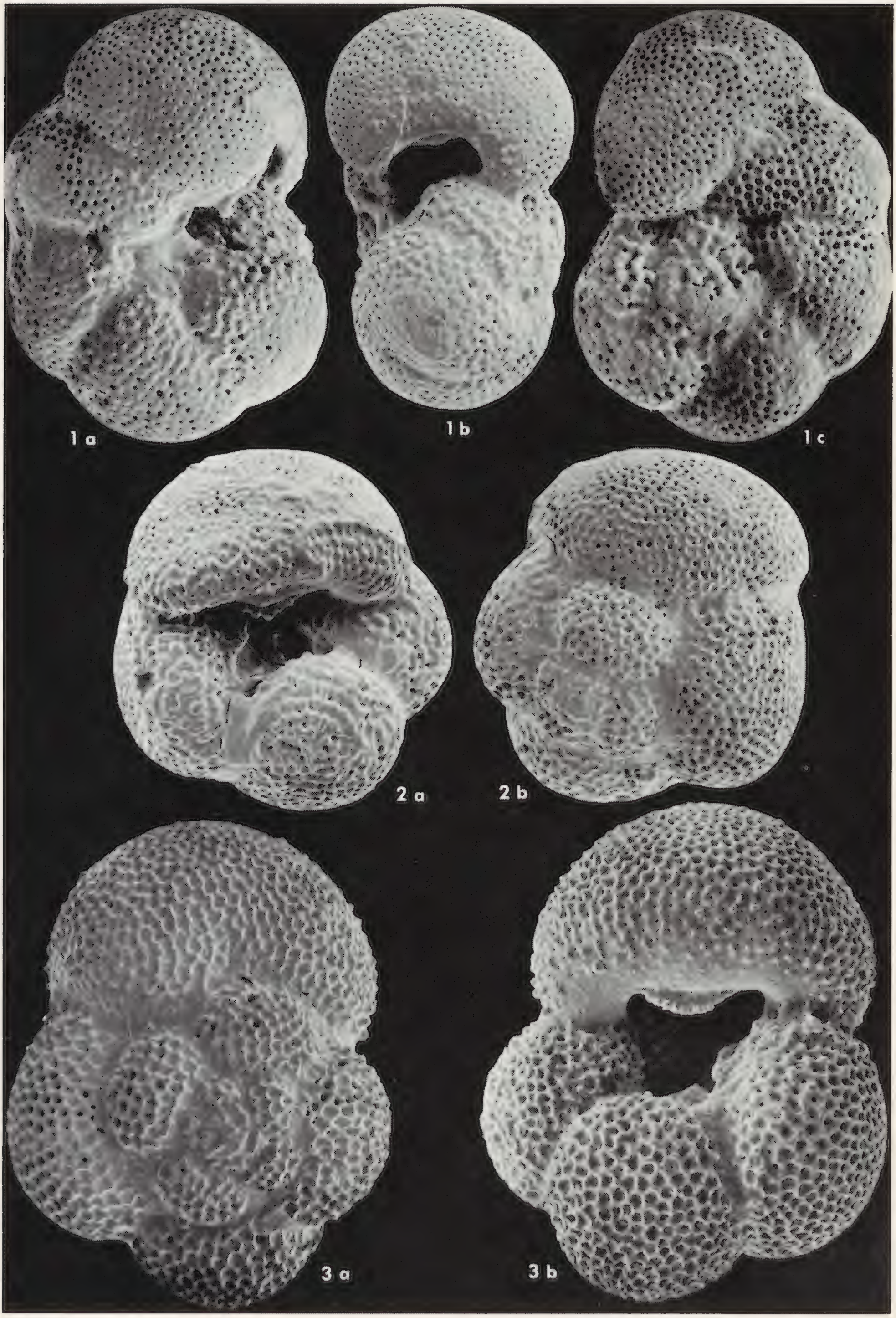


Plate 5

1969), and *Globigerina bulloides apertura,* which has not been recorded above Zone N. 19. Thus, it would appear that beds at the Gainer site, as well as those at the other localities assigned to the *Cancellaria* Faunizone, are of approximately the same age as beds referred to the *Ecphora* Faunizone (Zone N. 19), and in turn, to the Bowden Formation of Woodring (1925; 1928) and Palmer (1945).

The calcareous nannofossil assemblage in the Gainer beds is restricted to a few coccoliths and rare *Discoaster brouweri, Lithostromation perdurum,* and *Braarudosphaera bigelowi,* which fail to amplify or contradict the foraminiferal evidence for an early Pliocene age for these sediments.

## AGUEGUEXQUITE FORMATION

Beds which crop out on the north coast of the Isthmus of Tehuantepec, Mexico, are included in this study, because of faunal similarity to foraminiferal assemblages of the northern Gulf Coast and Atlantic Coastal Plain. Samples were collected by Harold E. and Emily H. Vokes from the lower part of the exposure, a dark gray clay, in a roadcut and quarry on Mexico Highway 180, 14 miles east of the junction with the road into Coatzacoalcos, Vera Cruz (TU 638). Perrilliat Montoya (1963) has described the mollusks from this area, and the beds have been variously considered as middle and upper Miocene in age (see also Contreras Velazquez, 1956, p. 52).

The predominant planktonic foraminifer at this locality is *Globigerinoides quadrilobatus quadrilobatus.* Additional forms were identified as listed below but are not illustrated.

*Globigerina bulloides apertura* Cushman
*Globigerina bulloides bulloides* d'Orbigny
*Globigerina juvenilis* Bolli
*Globigerinoides obliquus extremus* Bolli and Bermúdez
*Globigerinoides obliquus obliquus* Bolli
*Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny)
*Globigerinoides ruber* (d'Orbigny)
*Globorotalia (Turborotalia) acostaensis acostaensis* Blow
*Globorotalia (Turborotalia) acostaensis humerosa* Takayanagi and Saito
*Globorotalia (Globorotalia) cultrata* subspecies (dextral)
*Hastigerina (Hastigerina) siphonifera siphonifera* (d'Orbigny)
*Orbulina universa* d'Orbigny
*Sphaeroidinella dehiscens dehiscens* forma *immatura* (Cushman)

Benthonic foraminifera include forms reminiscent of late Pliocene and early Pleistocene species of the northern Gulf Coast (Akers and Dorman, 1964), especially *Angulogerina*

## PLATE 6
## ENCANTO FORMATION
## TU 635

Figures Page

1. *Globigerina* sp. . . . . 11
Maximum diameter, 0.36 mm
a. Spiral view, X 129
b. Edge view, X 128
c. Umbilical view, X 128

2. *Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny). . . . . 62
Maximum diameter, 0.56 mm
a. Spiral view, X 112
b. Edge view, X 112
c. Umbilical view, X 112

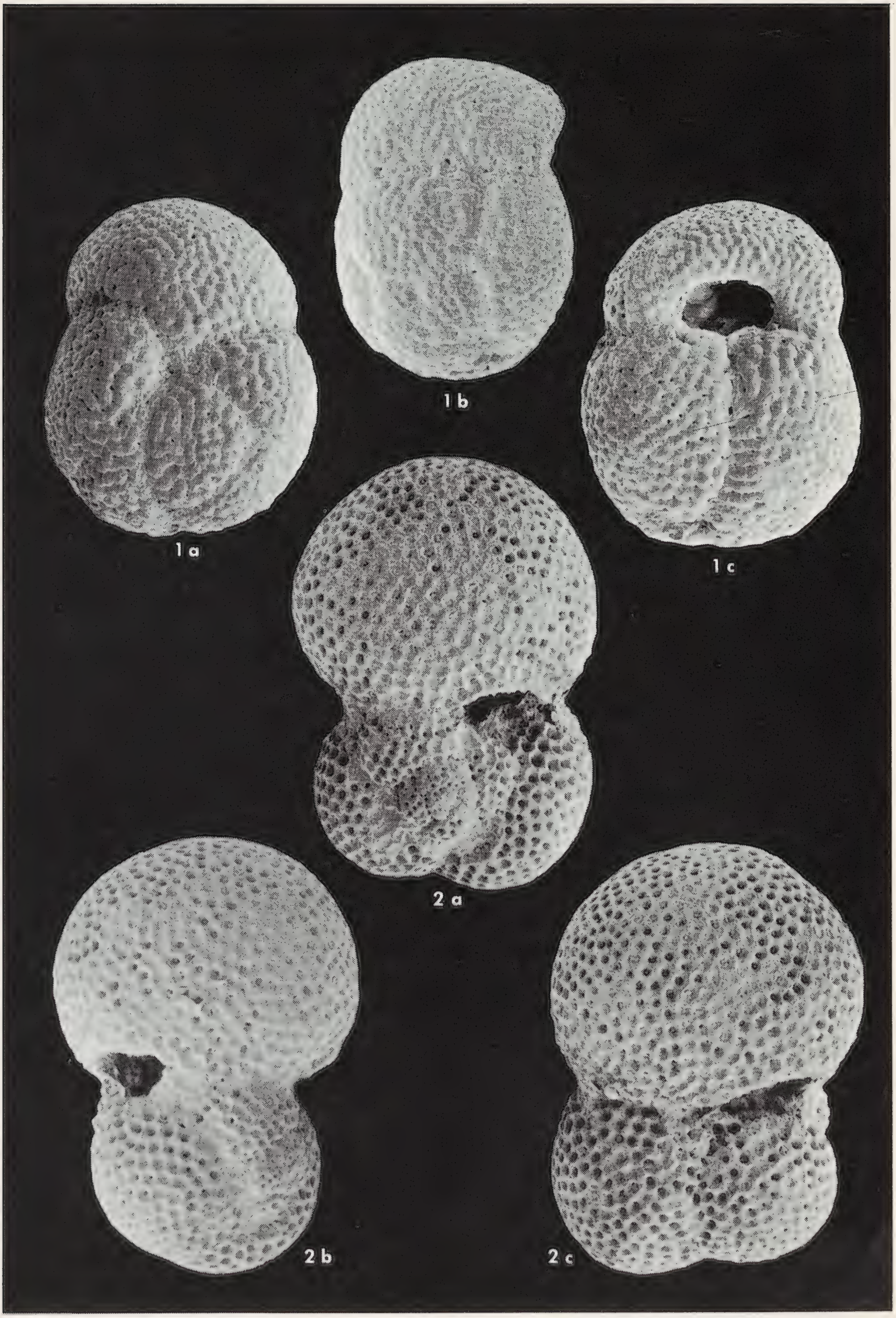


Plate 6

*holcki* Akers and Dorman, which, until this writing, has been identified only in the subsurface upper Pliocene-lower Pleistocene of Louisiana. The benthonic component is exceeded by the planktonic component of the assemblage, an anomaly (by northern Gulf of Mexico standards) in view of the large quantity of gravels and coarse sands in and interbedded with the clay.

Approximately 200 coccoliths occur per 20 mm of traverse (at X600) on calcareous nannoplankton slides. *Sphenolithus abies,* ubiquitous in upper Miocene to middle Pliocene sediments of pelagic origin, was not seen. *Discoaster brouweri, Discoaster pentaradiatus, Discoaster* cf. *Discoaster surculus, Discoaster variabilis,* and *Lithostromation perdurum* were identified. Rare, reworked Eocene species of *Discoaster* were observed.

The total assemblage of planktonic microfossils is suggestive of a middle to upper Pliocene age, and the presence of *Sphaeroidinella dehiscens dehiscens* forma *immatura* would seem to fix the exact position of the beds in Zone N. 19. *Globigerina bulloides apertura* has not been identified above Zone N. 19. The beds in at least this part of the Agueguexquite Formation are approximately correlative with the *Cancellaria* and *Ecphora* Faunizones of the Jackson Bluff Formation.

## YORKTOWN FORMATION
### Rice's Pit
### Plates 47-51

This is TU 613 on Harris Creek Road, near junction with Fox Hill Road (State Highway 167), just off U. S. Highway 258, Hampton, Virginia.

Several Yorktown sites are included in this study of which the above contained the highest ratio of planktonic to benthonic foraminifera. Additional localities investigated for planktonic microfossils are listed in the Locality data at the end of this report.

The Yorktown Formation was defined by Clark and Miller (1906, pp. 19-20) and is composed of sands, clays, shell marl, and coquinas. It has been considered to be of late Miocene age by most workers. Thickness at the outcrop is as much as 145 feet. McLean (1956) has reviewed most of the paleontologic research on the formation and has recorded the benthonic foraminiferal species in the York-James Peninsula of Virginia. His account of the planktonic species is incomplete due to their scarcity at most localities and the sketchy taxonomy of this group before the present decade.

This investigation disclosed the following planktonic foraminifera at Rice's Pit:

*Globigerina bulloides apertura* Cushman, pl. 47, fig. 3
*Globigerina bulloides bulloides* d'Orbigny, pl. 47, fig. 1, 2

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## PLATE 7
## ENCANTO FORMATION
## TU 635

Figures Page

1. *Globigerinoides obliquus obliquus* Bolli. . . . . 60
Maximum diameter, 0.51 mm
   a. Spiral view, X 119
   b. Edge view, X 115
   c. Umbilical view, X 119

2. *Sphaeroidinellopsis subdehiscens subdehiscens* Blow. . . . . 86
Maximum diameter, 0.44 mm
   a. Spiral view, X 143
   b. Edge view, X 140
   c. Umbilical view, X 143

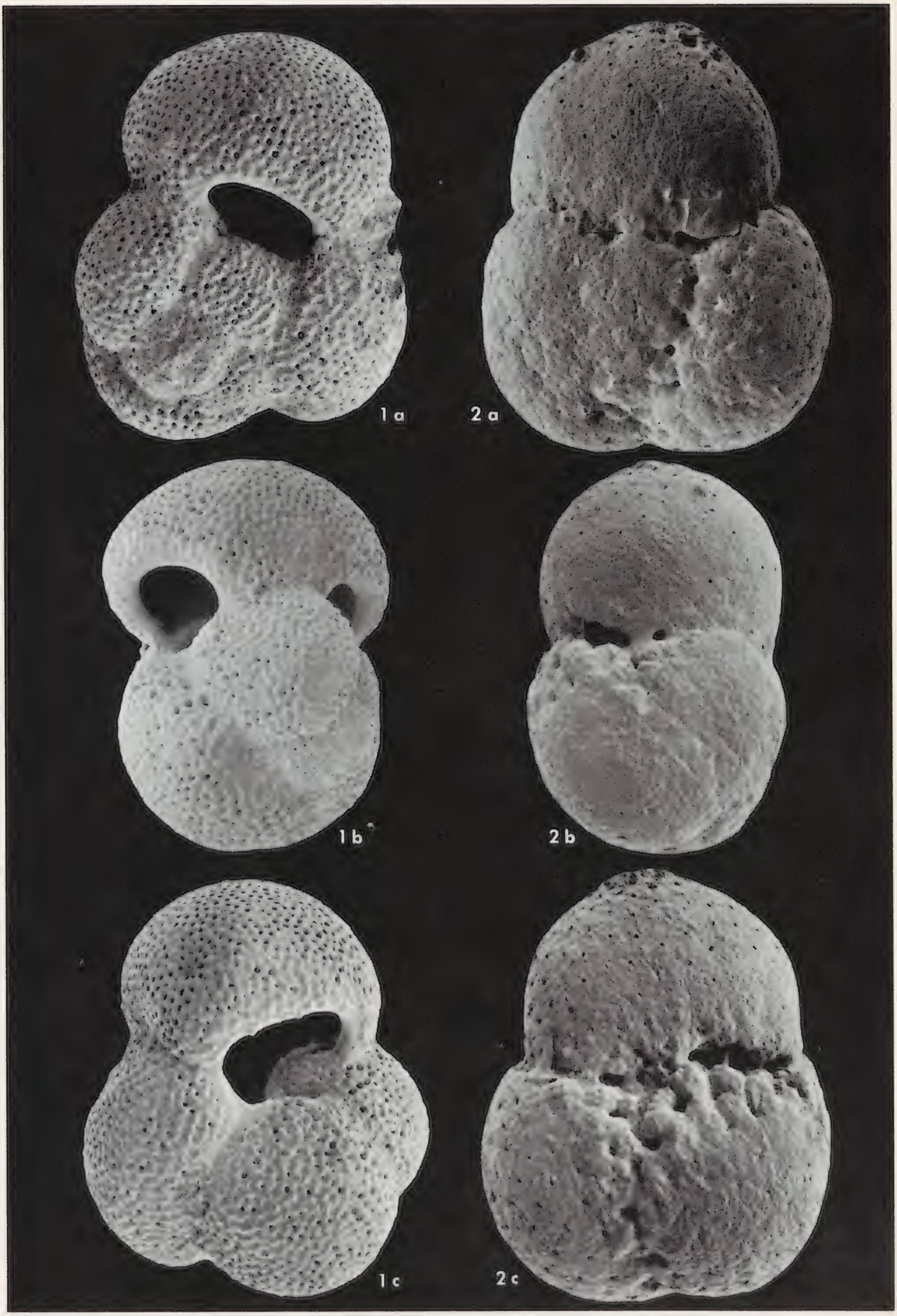


Plate 7

*Globigerina juvenilis* Bolli
*Globigerinita glutinata* (Egger)
*Globigerinoides bollii* Blow, pl. 48, fig. 2
*Globigerinoides conglobatus conglobatus* (Brady)
*Globigerinoides obliquus extremus* Bolli and Bermúdez, pl. 48, fig. 3
*Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny), pl. 49, fig. 1
*Globigerinoides ruber* (d'Orbigny), pl. 49, fig. 2
*Globoquadrina conglomerata* (Schwager)
*Globorotalia (Turborotalia) acostaensis humerosa* Takayanagi and Saito, pl. 48, fig. 1
*Globorotalia (Globorotalia) cultrata* subspecies, pl. 51, fig. 2
*Globorotalia (Turborotalia) praeoscitans,* new species, pl. 50, fig. 2; pl. 51, fig. 3
*Globorotalia (Globorotalia)* species, pl. 51, fig. 1
*Hastigerina (Hastigerina) siphonifera siphonifera* (d'Orbigny), pl. 50, fig. 1
*Orbulina universa* d'Orbigny
*Sphaeroidinellopsis subdehiscens subdehiscens* Blow, pl. 49, fig. 3

The predominant planktonic foraminifera at this locality, in order of highest frequency, are *Globigerina bulloides bulloides, Globorotalia (T.) acostaensis humerosa, Globigerinoides quadrilobatus quadrilobatus, Globigerinoides ruber,* and *Globigerina bulloides apertura.* Others are rare, one specimen to six specimens of each of the taxa having been found after 15 hours of searching through residues.

The calcareous nannoplankton here are small coccoliths (approximately 50 per 20 mm at X600) and occasional *Braarudosphaera bigelowi.* Discoasters are absent.

This type of calcareous nannofossil assemblage suggests not only a shallow environment of deposition but also temperatures lower than those so far seen in this investigation. Foraminiferal criteria support this conclusion in the predominance of *Globigerina bulloides bulloides* and the dearth of keeled *Globorotalia* specimens and species. Nevertheless, the planktonic foraminiferal assemblage is essentially a Jackson Bluff (late Choctawhatchee) one. The presence of *Globigerina bulloides apertura* precludes a zone later than Zone N. 19, and *Globoquadrina conglomerata* indicates a position later than at least the middle of Zone N. 18. *Globorotalia (Turborotalia) praeoscitans,* n. sp., has been seen only in Yorktown beds and in the Jackson Bluff Formation. The planktonic microfossil evidence argues strongly (1) for a correlation of the Yorktown Formation, at least that part exposed at Rice's Pit, with the Jackson Bluff Formation of north Florida and (2) that the circumglobal distributions of these taxa indicate an early to early middle Pliocene age for the Jackson Bluff and Yorktown Formations. Hazel (1971, p. 8) has

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PLATE 8
ENCANTO FORMATION
TU 635

Figures Page

1. *Globoquadrina dehiscens* (Chapman, Parr, and Collins). . . . . 92
Maximum diameter, 0.36 mm
a. Spiral view, X 179
b. Edge view, X 167
c. Umbilical view, X 180

2. *Globoquadrina altispira globosa* Bolli. . . . . 88
Maximum diameter, 0.52 mm
a. Spiral view, X 125
b. Edge view, X 120
c. Umbilical view, X 125

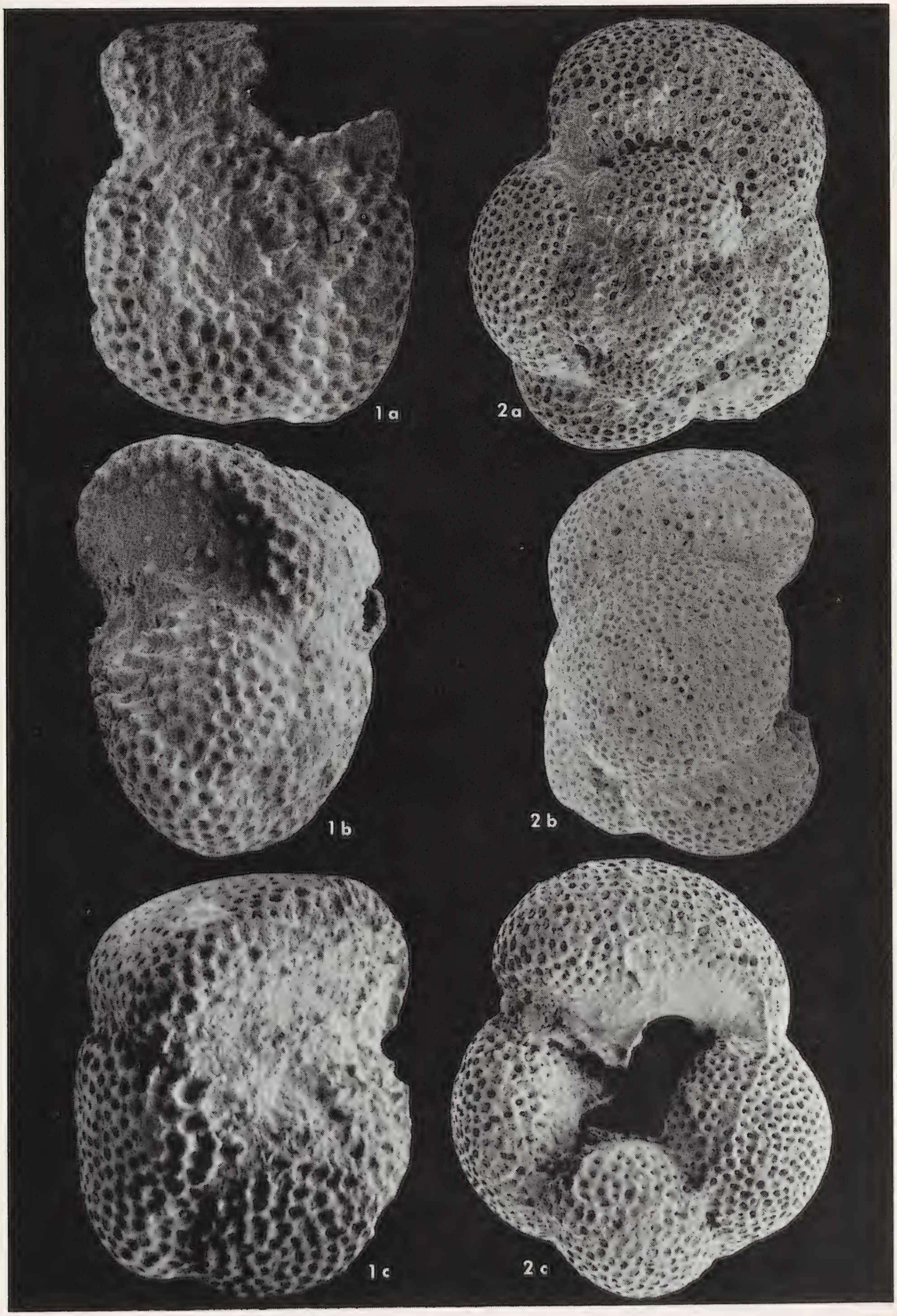


Plate 8

assigned portions of the Yorktown Formation to the early Pliocene and suggested that "the upper Miocene–lower Pliocene boundary in the Atlantic and Gulf Coastal Plain eventually will be revised further downward to include in the Pliocene more of the deposits that have been traditionally assigned to the upper Miocene."

Yorktown beds in the Lee Creek Mine at Aurora, North Carolina (see Locality data), have a planktonic assemblage of abundant individuals but relatively few species. The predominant species here is *Globigerina bulloides bulloides*. The second most frequently observed species is *Globorotalia (Turborotalia) praeoscitans*, n. sp. A few specimens of *Globorotalia (Turborotalia) acostaensis humerosa* were seen, and the following forms were rare:

*Globigerinita glutinata* (Egger)
*Globigerinoides obliquus obliquus* Bolli
*Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny)
*Globigerinoides ruber* (d'Orbigny)

The calcareous nannofossil assemblage is poor, as it is at Rice's Pit.

The planktonic microfossil assemblages are too impoverished here for a basis of exact correlation. The same may be said of TU 843 and the Lone Star Cement Pit, Chuckatuck, Virginia (see Locality data), where planktonic microfossils are rare.

## WACCAMAW FORMATION
## Plates 52-57

Planktonic foraminifera were obtained from the Waccamaw Formation at three localities, TU 558, TU 870, and TU 875, by examining 25 ml of material floated by means of tetrachloroethylene from each site. TU 558 is a pit locality at the north end of the runway at Crescent Beach Airport and south of the intracoastal waterway, South Carolina. TU 870 is also a pit site on the east side of North Carolina Highway 130, 2.8 miles north of "Old Dock School" and 0.6 miles north of intersection of road to Hallsboro, Columbus County, North Carolina. TU 875 is at Walker's Bluff on the west bank of the Cape Fear River, 9.5 miles south of Elizabethtown, North Carolina, via North Carolina Highway 87 and 1.5 miles through field of Mr. Monroe.

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## PLATE 9
## ENCANTO FORMATION
## TU 635

Figures Page

1. *Hastigerina (Hastigerina) siphonifera siphonifera* (d'Orbigny). . . . . 124
Maximum diameter, 0.58 mm
a. Spiral view, X 104
b. Edge view, X 112
c. Umbilical view, X 113

2. *Globorotalia (Globorotalia) cultrata menardii* (Parker, Jones and Brady). . . . . 98
Maximum diameter, 0.47 mm
a. Spiral view, X 101
b. Edge view, X 101
c. Umbilical view, X 102

3. *Globorotalia* sp. . . . . 11
Maximum diameter, 0.29 mm
a. Spiral view, X 202
b. Edge view, X 200
c. Umbilical view, X 202

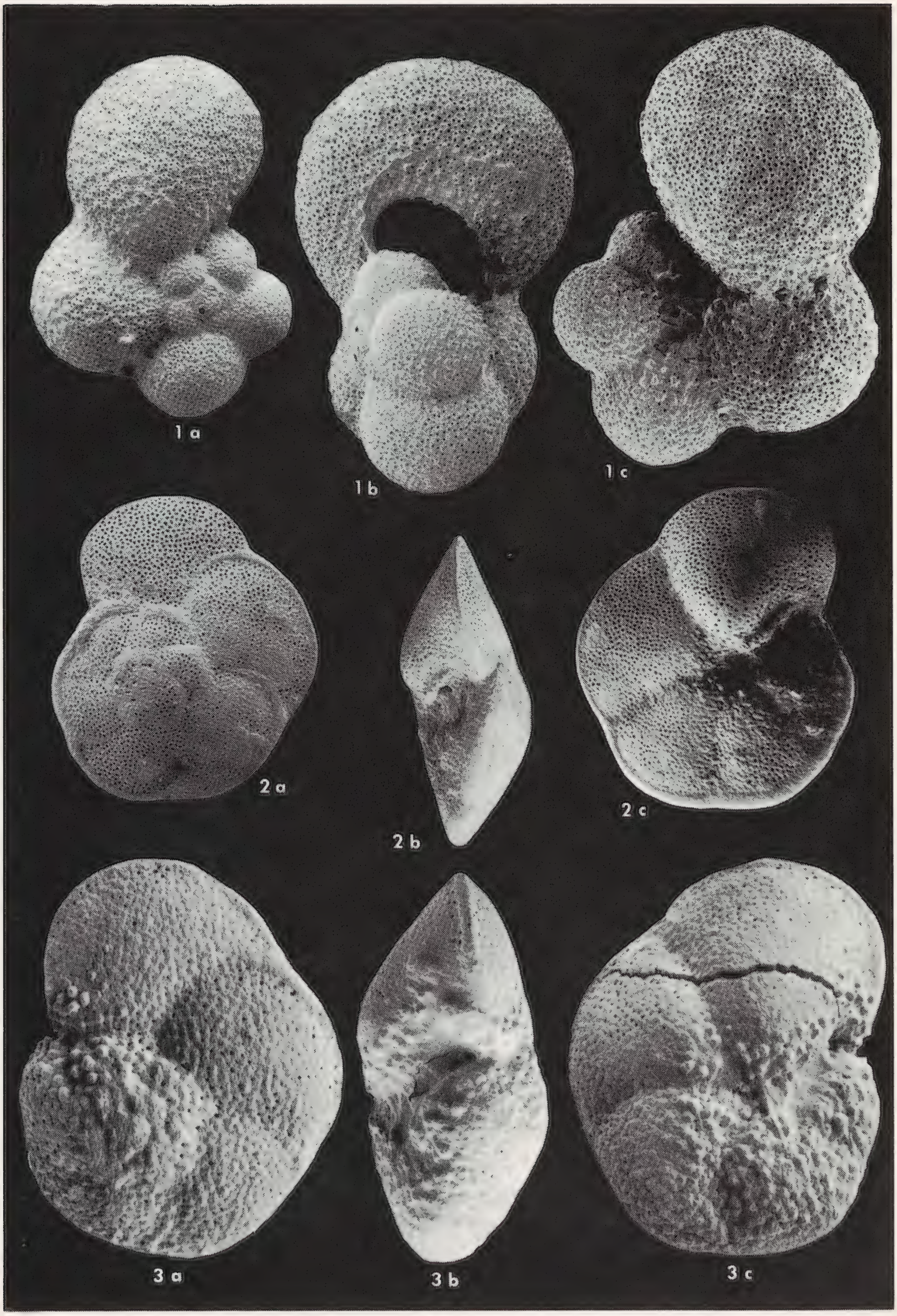


Plate 9

The Waccamaw Formation was named by Dall (1892, p. 209) for deposits approximately 25 feet in thickness, along the Waccamaw River in South Carolina. In southern North Carolina this formation consists mainly of medium to coarse quartz sands with pebbles, shell beds, and some clayey sand units. It overlies Cretaceous and Eocene sediments unconformably and is unconformably overlain by Pleistocene sands, gravels, and clays.

DuBar (1959) has regarded the Waccamaw and Croatan beds of the Carolinas as pre-Pamlico Pleistocene, although they had long been considered to be of Pliocene age (Cooke, Gardner, and Woodring, 1943). Richards (1969, p. 607) recently has expressed the opinion that the upper part of the Waccamaw and Croatan formations of the Carolinas and the upper part of the Caloosahatchee Formation of Florida "could be Pliocene or early Pleistocene." He believes that the lower part of these formations is definitely Pliocene, particularly the Caloosahatchee, on the basis of a high percentage of extinct molluscan species. The benthonic foraminifera at several Waccamaw localities indicated a late Miocene age to Gibson (1962, p. 22), who believed that this formation is contemporaneous with the Yorktown and Duplin formations.

DuBar (1959, p. 6) reviewed the Lyellian percentage method and assessed it as a spurious means of determining the precise age of a Cenozoic formation. He considered the Caloosahatchee, as well as the Waccamaw, to be Pleistocene, and Puri and Vernon (1964, p. 231) agreed with him in this conclusion.

The following planktonic foraminifera were found in the Waccamaw Formation at TU 875:

*Globigerina borealis* Brady
*Globigerina bulloides bulloides* d'Orbigny, pl. 52, fig. 4
*Globigerina juvenilis* Bolli, pl. 52, fig. 2
*Globigerinita uvula* (Ehrenberg), pl. 52, fig. 1
*Globigerinoides obliquus obliquus* Bolli, pl. 53, fig. 2
*Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny), pl. 53, fig. 3
*Globigerinoides ruber* (d'Orbigny), pl. 53, fig. 1
*Globorotalia (Turborotalia) acostaensis humerosa* Takayanagi and Saito, pl. 54, fig. 2
*Globorotalia (Turborotalia) acostaensis pseudopima* Blow
*Globorotalia (Globorotalia) cultrata menardii* (Parker, Jones and Brady), pl. 55, fig. 3
*Globorotalia (Turborotalia) inflata* (d'Orbigny), pl. 52, fig. 3
*Globorotalia (Globorotalia) truncatulinoides* (d'Orbigny), pl. 55, fig. 1
*Globorotalia (Globorotalia)* species, pl. 55, fig. 2
*Globorotaloides hexagona hexagona* (Natland)

## PLATE 10
## YELLOW RIVER FORMATION
## COSSON FARM

Figures Page

1. *Globigerinoides obliquus obliquus* Bolli. . . . . 60
Maximum diameter (a-c), 0.50 mm

   a. Spiral view, X 126
   b. Umbilical view, X 126
   c. Edge view, X 125
   d. Umbilical view of another specimen, X 140. Maximum diameter, 0.34 mm

2. *Orbulina universa* d'Orbigny. . . . . 74
Maximum diameter, 0.48 mm

Part of test removed to show early *Globigerina* stage, X 126

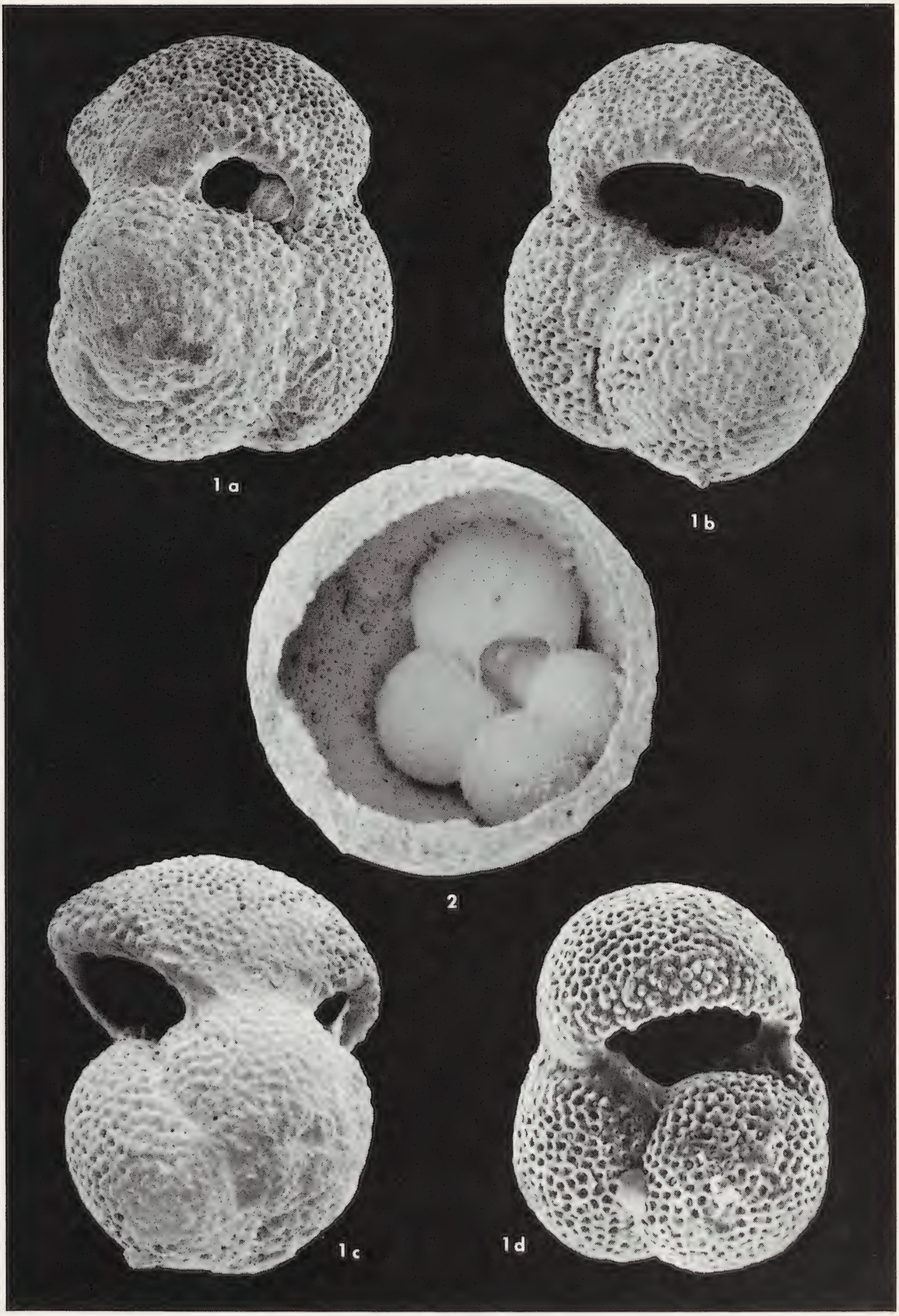


Plate 10

*Hastigerina (Hastigerina) siphonifera siphonifera* (d'Orbigny), pl. 54, fig. 1
*Orbulina universa* d'Orbigny

Planktonic foraminifera are rare in the Waccamaw Formation at TU 875. After approximately 100 hours of examination (by binocular microscope) of material floated by tetrachloroethylene from residues, however, 234 specimens of *Globigerinoides ruber* and 90 specimens of *Globigerinoides quadrilobatus quadrilobatus* were counted. Thirty-seven specimens of *Globorotalia (T.) acostaensis humerosa* were seen. A single *Globorotalia (G.) cultrata menardii* (sinistral) and two specimens of *Globorotalia truncatulinoides* were found. Low counts (1-5) were made of the remaining forms listed above.

Use of rare index fossils in the recognition of boundaries on an intercontinental scale is not an ideal approach in biostratigraphy, and yet several small pieces may be all that are needed to complete our understanding of the picture-puzzle. The environment of deposition of the Waccamaw Formation did not leave us any abundance of data, but several planktonic keys relate a version that is consistent with the total data.

Ericson, Ewing, and Wollin (1963), Akers (1965), and Poag and Akers (1967) proposed that *Globorotalia (G.) truncatulinoides* occurs in abundance only above the Pliocene-Pleistocene boundary. This conclusion seemed appropriate for at least the Gulf of Mexico and the Atlantic Ocean. Additional work on deepsea cores from the Pacific (Parker, 1967) and the Gulf of Mexico (Lamb, 1969) suggests strongly that the evolutionary first-occurrence of this species is above the boundary. This interpretation is tenable if we conclude that sporadic and rare occurrences of *Globorotalia (G.) truncatulinoides* below the boundary are not valid and represent contamination in the coring process. Both Bayliss (1969) and Lamb (1969) report that this species appears for the first time above the base of the Calabrian in the type area of the Calabrian at Santa Maria di Catanzaro in southern Italy.

The single sinistrally coiled *Globorotalia (G.) cultrata menardii* found here (pl. 55, fig. 3) corresponds morphologically with the "single fairly uniform race above the boundary" (Ericson, *et al.*, 1963). The specimen also resembles those found above the boundary in the northern Gulf of Mexico

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PLATE 11
YELLOW RIVER FORMATION
COSSON FARM

Figures Page

1. *Globoquadrina altispira globosa* Bolli. . . . . 88
Maximum diameter, 0.57 mm
a. Spiral view, X 98
b. Umbilical view, X 99
c. Edge view, X 99

2. *Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny). . . . . 62
Maximum diameter, 0.51 mm
a. Spiral view, X 105
b. Umbilical view, X 105

3. *Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny). . . . . 62
Maximum diameter, 0.69 mm
a. Spiral view, X 92
b. Edge view, X 91
c. Umbilical view, X 93

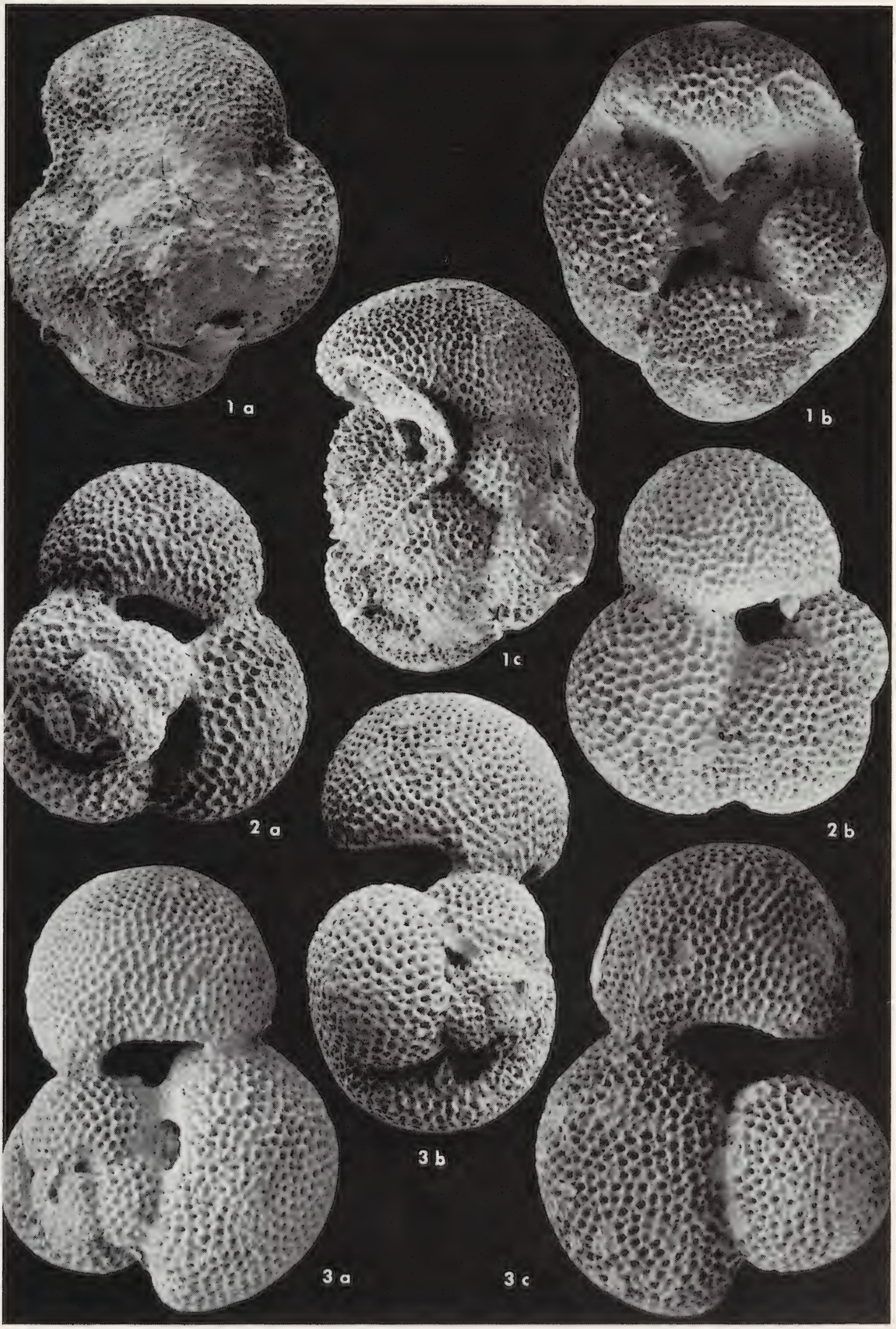


Plate 11

both in coiling direction and test morphology (Akers, 1965). *Globorotalia (T.) acostaensis pseudopima* and *Globigerina borealis* point to a Quaternary or late Pliocene age.

Since *Globigerinoides obliquus obliquus* becomes extinct within Zone N. 22 (Blow, 1969), the presence of this form precludes a middle Pleistocene to Holocene age. The species discussed above, then, especially *Globorotalia (G.) truncatulinoides,* which precludes a pre-Quaternary age, indicate that the Waccamaw at this locality is early Pleistocene in age (the later part of Zone N. 21 to the early part of Zone N. 22).

The material from TU 875 is a composite sample from an interval of ten feet. The association of *Globorotalia (G.) cultrata menardii* with *Globorotalia (T.) inflata* suggests that both a warm and a cool stage are represented in this interval. It must be pointed out that the beds at TU 875 are not necessarily the same age as sediments at other localities which have been assigned to the Waccamaw. It is possible, too, that the Caloosahatchee Formation is older than this material.

TU 870 is similar faunally to TU 875. Calcareous nannoplankton are rare at both sites, and the frequency of planktonic foraminifera is about the same, although *Globorotalia (G.) cultrata menardii* and *Globorotalia (G.) truncatulinoides* were not identified at TU 870. It is, therefore, not possible to be so specific as to the age of the beds at TU 870. They may be the same age as at 875, but this cannot be confirmed as yet.

The following planktonic foraminifera occur in the Waccamaw Formation at TU 870:

*Globigerina borealis* Brady
*Globigerina bulloides bulloides* d'Orbigny, pl. 57, fig. 3
*Globigerina juvenilis* Bolli
*Globigerinita glutinata* (Egger)
*Globigerinita uvula* (Ehrenberg)
*Globigerinoides conglobatus conglobatus* (Brady)
*Globigerinoides obliquus obliquus* Bolli, pl. 56, fig. 1
*Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny), pl. 56, fig. 2
*Globigerinoides ruber* (d'Orbigny), pl. 56, fig. 3
*Globorotalia (Turborotalia) acostaensis humerosa* Takayanagi and Saito, pl. 57, fig. 1

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## PLATE 12
## YELLOW RIVER FORMATION
## COSSON FARM

Figures Page

1. *Globigerina juvenilis* Bolli. . . . . 52
Maximum diameter, 0.26 mm
   a. Umbilical view, X 197
   b. Edge view, X 196
   c. Spiral view, X 196

2. *Hastigerina (Hastigerina) siphonifera siphonifera* (d'Orbigny) . . . . . 124
   a,c. Umbilical and spiral views, X 141. Maximum diameter, 0.42 mm
   b. Edge view of another specimen, X 140. Maximum diameter, 0.44 mm

3. *Sphaeroidinellopsis seminulina kochi* (Caudri). . . . . 82
Maximum diameter, 0.69 mm
   a. Umbilical view, X 94
   b. Edge view, X 91
   c. Spiral view, X 92

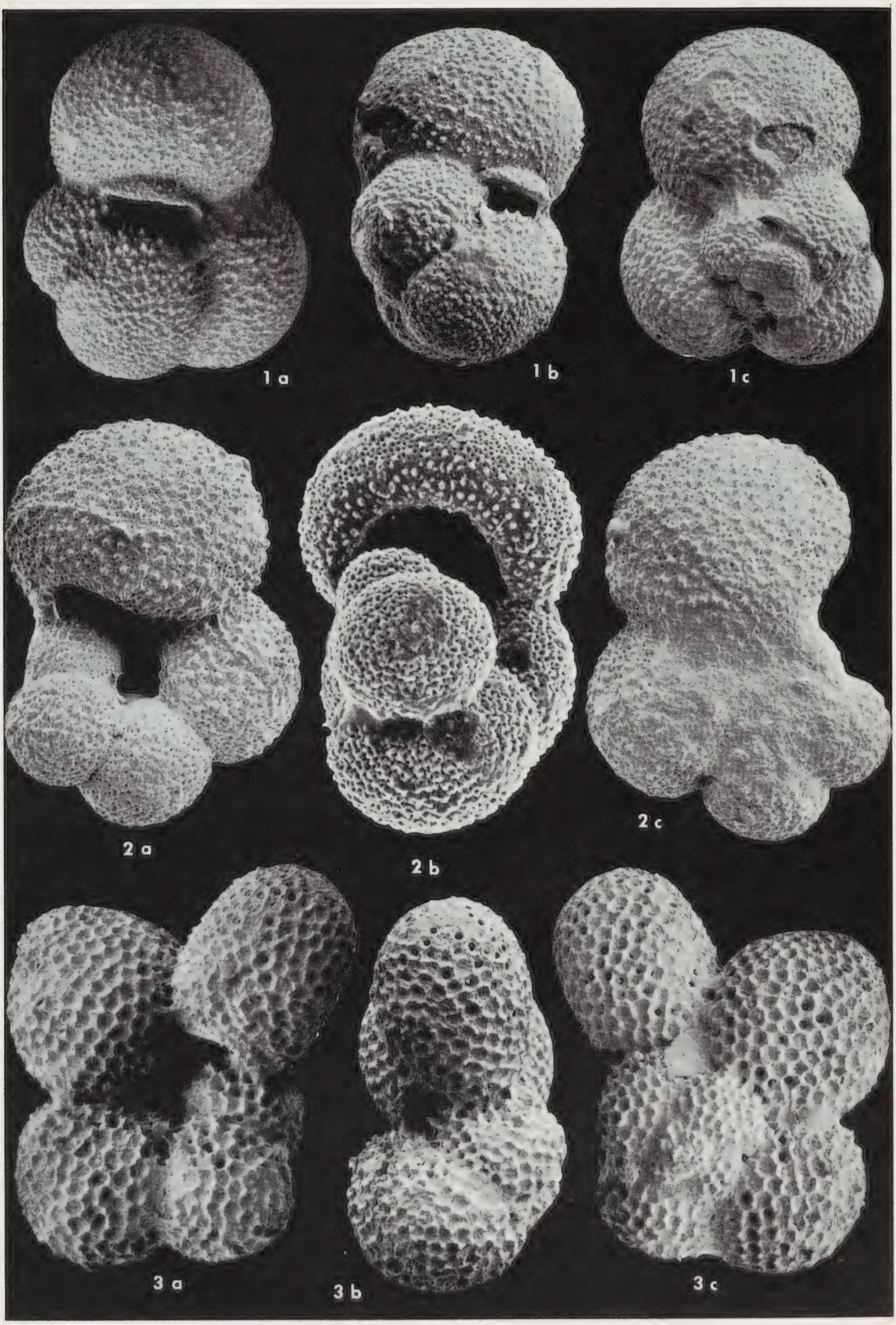


Plate 12

*Globorotalia (Turborotalia) inflata* (d'Orbigny), pl. 57, fig. 2
*Orbulina universa* d'Orbigny

Planktonic foraminifera are rare at TU 558, only four specimens having been found. Three of these represent *Globigerinoides ruber* (d'Orbigny), and the fourth is *Globigerinita glutinata* (Egger).

## MOÍN FORMATION
### Plates 58-60

Harold E. and Emily H. Vokes provided the writer with material from their locality, TU 954, a hill-cut behind the Standard Fruit Company box factory, just west of Cemetery Pueblo Neuvo, about two km west of Limon, Costa Rica. Sands and clays of unknown thickness here contain abundant mollusks. Gabb (1895, p. 80) named the formation and considered it post-Pliocene. It is interesting that subsequent workers interpreted the molluscan fauna as Pliocene in age and suggested that Gabb had mistranslated into Spanish the term "post-Pliocene" for "later Pliocene." Harold E. and Emily H. Vokes (personal communication) consider the molluscan assemblage to be of Pleistocene age.

The following planktonic foraminifera were identified in the Moín Formation at TU 954:

*Globigerinoides conglobatus conglobatus* (Brady), pl. 58, fig. 1, 2
*Globigerinoides obliquus obliquus* Bolli, pl. 58, fig. 3
*Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny), pl. 59, fig. 1
*Globigerinoides quadrilobatus sacculifer* (Brady), pl. 59, fig. 2
*Globigerinoides ruber* (d'Orbigny), pl. 58, fig. 4
*Globoquadrina dutertrei* (d'Orbigny), pl. 60, fig. 2
*Hastigerina (Hastigerina) siphonifera siphonifera* (d'Orbigny), pl. 60, fig. 1
*Orbulina universa* d'Orbigny
*Pulleniatina obliquiloculata obliquiloculata* (Parker and Jones), pl. 60, fig. 3
*Sphaeroidinella dehiscens dehiscens* (Parker and Jones), pl. 59, fig. 3

*Globigerinoides quadrilobatus quadrilobatus* is the predominant planktonic foraminifer here. At least three specimens of the other

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## PLATE 13
## YELLOW RIVER FORMATION
## COSSON FARM

Figures — Page

1. *Globorotalia (Globorotalia) cultrata menardii* (Parker, Jones and Brady). . . . . 98
Maximum diameter, 0.43 mm
a. Spiral view, X 127
b. Edge view, X 127
c. Umbilical view, X 126

2. *Globorotalia (Turborotalia) minima* Akers. . . . . 114
Maximum diameter, 0.26 mm
a. Spiral view, X 195
b. Edge view, X 193
c. Umbilical view, X 196

3. *Globorotalia (Turborotalia) siakensis* (LeRoy). . . . . 122
Maximum diameter, 0.39 mm
a. Spiral view, X 147
b. Edge view, X 147
c. Umbilical view, X 147

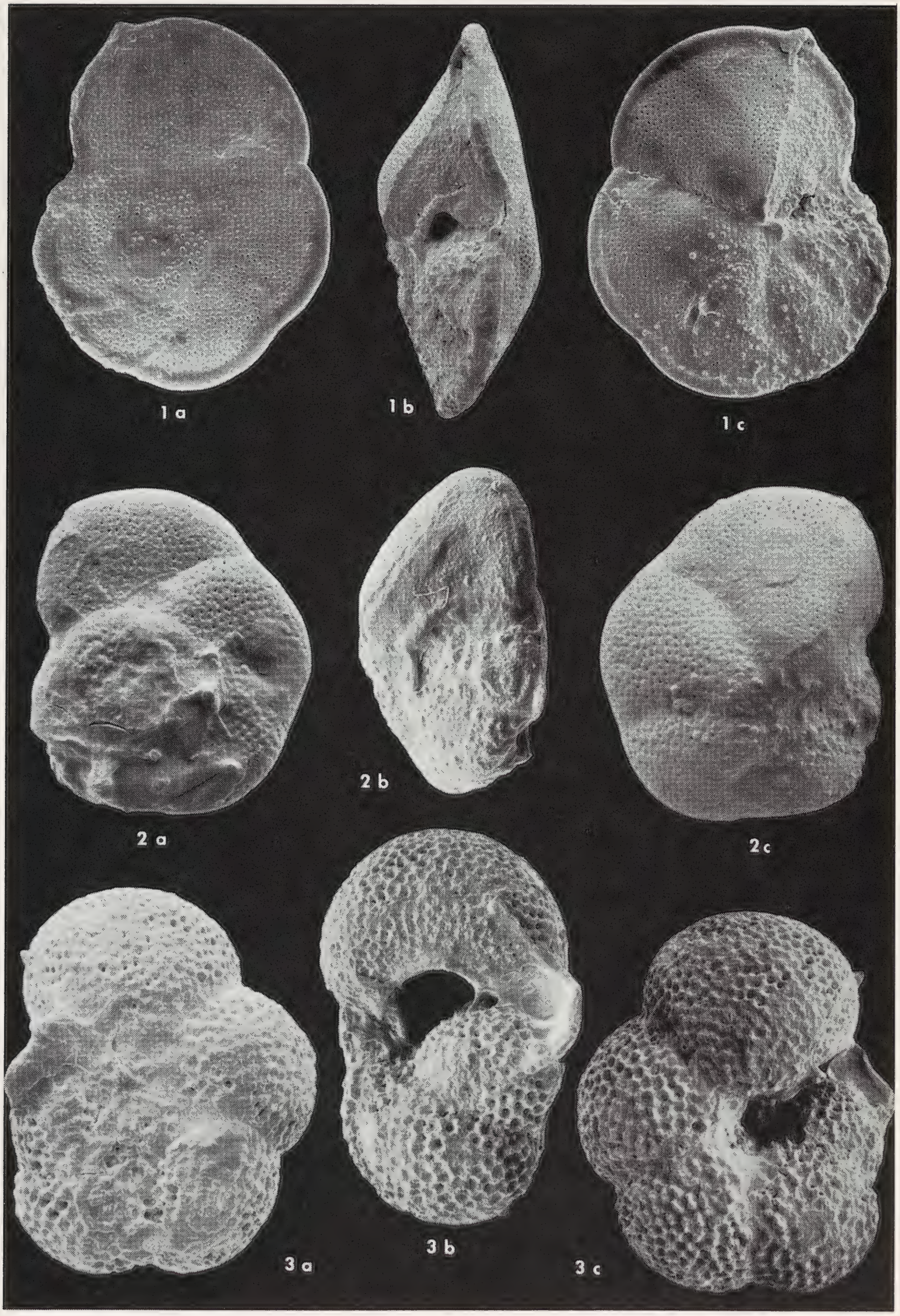


Plate 13

taxa listed above were found. It is curious that no representatives of *Globorotalia* were seen, although the assemblage is otherwise a tropical one.

Several of the forms listed above appear for the first time in Pliocene sediments, but they are not found in higher frequencies below the Pleistocene. *Globoquadrina dutertrei* is one of these, and it is not typically developed until the lower Quaternary (Parker, 1967, p. 168). The high frequency of *Pulleniatina obliquiloculata obliquiloculata* and *Sphaeroidinella dehiscens dehiscens* (with the exclusion of *Sphaeroidinellopsis*) are indicative of the Quaternary, although these taxa are reported to have an origin in the Pliocene (Zone N. 19). The benthonic foraminifera are of modern aspect, all of the species occuring in the late Quaternary assemblages of the Mississippi River Mudlumps (Andersen, 1961).

Calcareous nannofossils are in low frequency. Discoasters are absent, and even small coccoliths are rare. The absence of discoasters suggests a post-Pliocene age, but their absence might also be due to unfavorable environmental factors.

The writer believes that the Moín Formation at TU 954 is of early Pleistocene age. This interpretation is reconcilable with all faunal data available and best fits the planktonic microfossil data as herein reviewed.

## VI. SYSTEMATIC PALEONTOLOGY

Order FORAMINIFERIDA Eichwald, 1830

Superfamily GLOBIGERINACEA Carpenter, Parker and Jones, 1862

Family GLOBIGERINIDAE Carpenter, 1862

Genus GLOBIGERINA d'Orbigny, 1826

GLOBIGERINA BOREALIS Brady

*Globigerina bulloides* d'Orbigny, "arctic variety," BRADY, 1878, Ann. Mag. Nat. Hist. (ser. 5), vol. 1, p. 435, pl. 21, figs. 10a-c.

*Globigerina bulloides* d'Orbigny variety *borealis* BRADY, 1881, Ann. Mag. Nat. Hist. (ser. 5), vol. 8, no. 48, p. 412, (no figure).

*Globigerina bulloides* d'Orbigny var. *borealis* Brady. BRADY, 1882, Roy. Soc. Edinburgh, Proc., vol. 11, (1880-1882), no. 111, p. 716, (no figure).

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PLATE 14
RED BAY FORMATION ?
BLOUNT'S CREEK

Figures Page

1. *Globigerina nepenthes* Todd. . . . . 52
   Maximum diameter, 0.33 mm
   a. Umbilical view, X 146
   b. Spiral view, X 145

2. *Sphaeroidinellopsis seminulina seminulina* (Schwager). . . . . 84
   Maximum diameter, 0.64 mm
   a. Umbilical view, X 91
   b. Spiral view, X 90

3. *Globigerina* cf. *G. druryi decoraperta* Takayanagi and Saito. . . . . 50
   Maximum diameter, 0.33 mm
   a. Umbilical view, X 170
   b. Spiral view, X 168

4. *Globigerina bulloides bulloides* d'Orbigny. . . . . 48
   Maximum diameter, 0.46 mm
   a. Spiral view, X 126
   b. Umbilical view, X 127

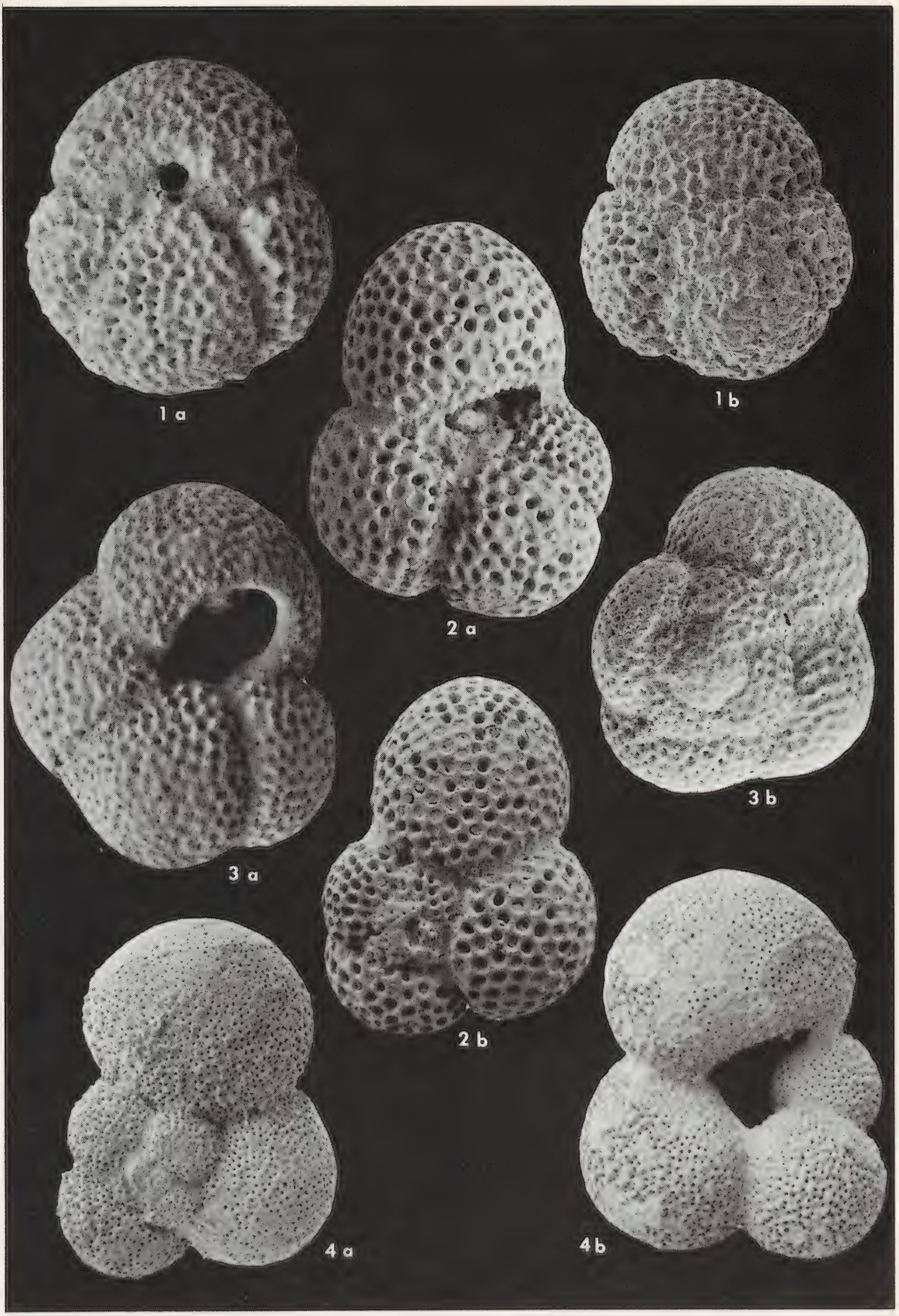


Plate 14

*Globigerina pachyderma* (Ehrenberg). BRADY, 1884, Rept. Voy. *Challenger,* Zool., vol. 9, p. 600, pl. 114, figs. 19, 20. (?non *Aristerospira pachyderma* Ehrenberg 1861).

*Globigerina bulloides* d'Orbigny var. *borealis* Brady. BANNER and BLOW, 1960, Cushman Found. Foram. Res., Contr., vol. 11, pp. 4-5, pl. 3, figs. 4a-c (lectotype designated).

*Globigerina borealis* Brady. BLOW, 1969, Proc. First International Conference on Planktonic Microfossils, vol. 1, p. 316 (no figure).

"The small tumid trochoid test consists of a fairly rapidly enlarging series of about 14 chambers arranged in about 3 whorls. The trochospire is low and consequently the dorsal surface is only slightly convex. The chambers are uniformly inflated but partially embracing and considerably appressed. About 4 chambers are present in the last whorl with the earlier whorls having about 5 chambers. The equatorial profile is subcircular to ovate and the equatorial periphery is weakly lobulate. The axial profile is suboval and the axial periphery smoothly rounded. The umbilicus is very small, almost closed, but depressed. The dorsal sutures are initially obscure but in the last whorl both the spiral and intercameral sutures are slightly depressed and fairly distinct. The later dorsal intercameral sutures are radial, meeting the spiral suture almost at right angles. The ventral sutures are distinct, slightly depressed and nearly radial. The aperture is a long low arch, interiomarginal, umbilical in position, not totally restircted to the deepest part of the umbilical depression. The aperture is bordered by a greatly thickened and broad rim. The test wall is uniformly and finely perforate and is characteristically thick. The test surface is practically smooth with only traces of an original fine hispidity. Maximum diameter of lectotype: 0.31 mm." (Banner and Blow, 1960)

Lectotype: British Museum (Natural History) 1959.7.1.1; collected by the North Polar Expedition of 1875-76, from the most northern sounding, 83° 19' N., depth 72 fathoms, and identified by Brady.

*Discussion:* Few specimens were identified in this investigation that are referable to this species. A single specimen from the Waccamaw (TU 875, Walker's Bluff, Bladen County, North Carolina) is typical.

The writer follows Blow in the choice of this taxon over "*Globigerina pachyderma* (Ehrenberg)" of some workers. Forms identical to the lectotype are said to range from within Zone N. 20 to Zone N. 23.

## GLOBIGERINA BULLOIDES APERTURA Cushman

Pl. 19, fig. 1; Pl. 21, fig. 3;
Pl. 30, fig. 1; Pl. 31, fig. 1;
Pl. 37, fig. 1; Pl. 42, fig. 1;
Pl. 47, fig. 3

*Globigerina apertura* CUSHMAN, 1918, U. S. Geol. Surv., Bull. 676, p. 57, pl. 12, figs. 8a-c.

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## PLATE 15
## RED BAY FORMATION ?
## BLOUNT'S CREEK

Figures — Page

1. *Globoquadrina altispira globosa* Bolli. . . . . 88
Maximum diameter, 0.45 mm
   a. Spiral view, X 136
   b. Umbilical view, X 140

2. *Globigerinita uvula* (Ehrenberg). . . . . 72
Maximum diameter, 0.30 mm
   a. Apertural view, X 172
   b. Opposite view, X 168

3. *Globoquadrina dehiscens* (Chapman, Parr, and Collins). . . . . 92
Maximum diameter, 0.45 mm
   a. Umbilical view, X 126
   b. Spiral view, X 122
   c. View of wall (spiral side), X 630

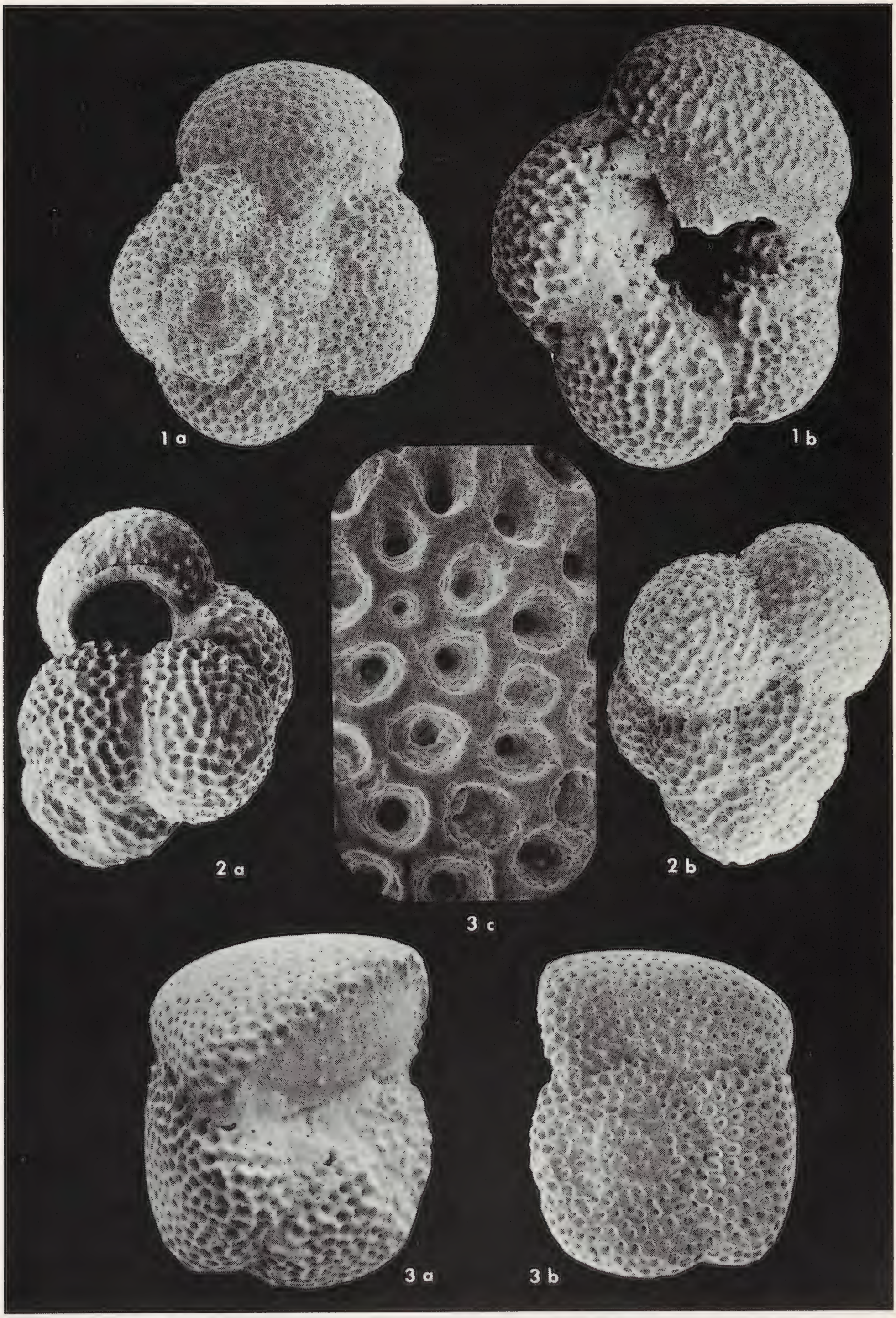


Plate 15

*Globigerina apertura* Cushman. BLOW, 1959, Bull. Amer. Paleontology, vol. 39, no. 178, pp. 172, 173, pl. 8, figs. 35a-b.

*Globigerina riveroae* BOLLI and BERMÚDEZ, 1965, Boletin Informativo, Asociacion Venezolana de Geologia, Min. y Pet., vol. 8, no. 5, pp. 137, 138, pl. 1, figs. 1-6.

*Globigerina bulloides apertura* Cushman. BLOW, 1969, Proc. First International Conference on Planktonic Microfossils, vol. 1, p. 317, pl. 12, fig. 8.

"Test spiral, depressed, all the chambers visible from the dorsal side, the four chambers making the last-formed coil visible from the ventral side chambers rapidly increasing in size; aperture very large, semicircular, opening into the central umbilical cavity. Diameter, 0.50 mm. This species may be distinguished by its extremely large semicircular aperture, compressed test, and few chambers." (Cushman, 1918)

Holotype: USNM 325323; Yorktown Formation, Suffolk, Virginia.

*Discussion:* Range is from Zone N. 16 to Zone N. 19 and questionably the early part only of Zone N. 20, according to Blow.

## GLOBIGERINA BULLOIDES BULLOIDES d'Orbigny

Pl. 14, fig. 4; Pl. 30, fig. 2;
Pl. 31, fig. 2, Pl. 34, fig. 1;
Pl. 37, fig. 3; Pl. 41, fig. 1;
Pl. 47, figs. 1, 2; Pl. 52, fig. 4;
Pl. 57, fig. 3

*"Polymorphium tuberosum et globiferum"* SOLDANI, 1791 (part), Testaceogr. ac Zoophytogr., vol. 1, pt. 2, p. 117, pl. 123, fig. 0 (not figs. H, I, and P, according to Banner and Blow, 1960, p. 3).

*Globigerina bulloides* D'ORBIGNY, 1826, Ann. Sci. Nat. (ser. 1), vol. 7, p. 277, list No. 1.

*Globigerina bulloides* d'Orbigny. BANNER and BLOW, 1960, Cushman Found. Foram. Res., Contr., vol. 11, pp. 3-4, pl. 1, figs. 1a-c (lectotype), 4.

*Globigerina bulloides* d'Orbigny. PARKER, 1962, Micropaleontology, vol. 8, no. 2, p. 221, pl. 1, figs. 1-8.

*Globigerina bulloides bulloides* d'Orbigny. BLOW, 1969, Proc. First International Conference on Planktonic Microfossils, vol. 1, pp. 316-317, pl. 14, figs. 1, 2.

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## PLATE 16
## RED BAY FORMATION ?
## BLOUNT'S CREEK

Figures Page

1. *Globigerinoides obliquus obliquus* Bolli. . . . . .60
Maximum diameter, 0.51 mm
a. Umbilical view, X 119
b. Spiral view, X 126

2. *Globigerinoides* sp. . . . . .14
Maximum diameter, 0.55 mm
a. Spiral view, X 108
b. Umbilical view, X 112

3. *Globigerinoides ruber* (d'Orbigny). . . . . .66
Maximum diameter, 0.44 mm
a. Spiral view, X 126
b. Umbilical view, X 125

4. *Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny). . . . . .62
Maximum diameter, 0.56 mm
a. Spiral view, X 108
b. Umbilical view, X 122

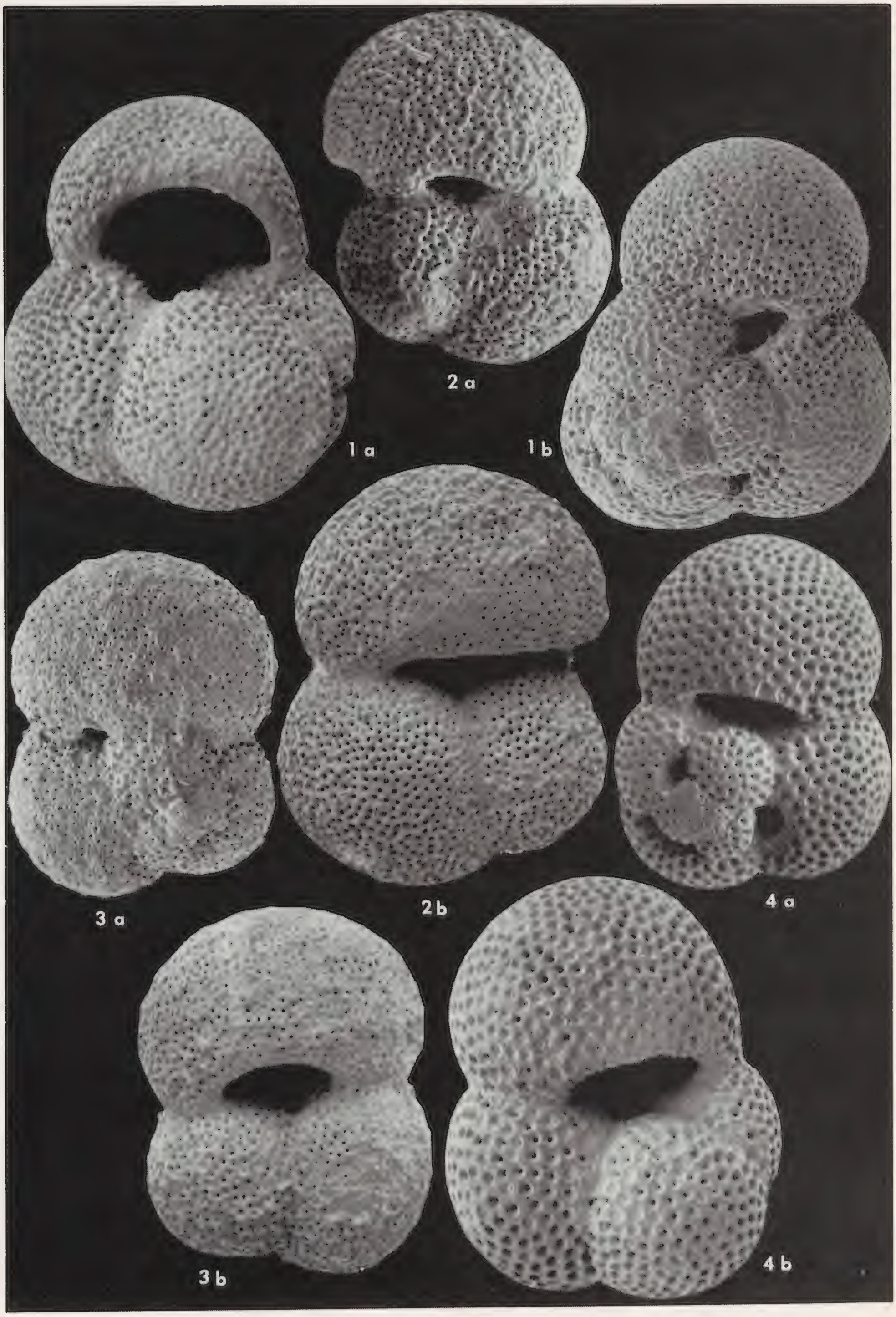


Plate 16

"The small tumid trochoid test consists of a fairly rapidly enlarging series of about 14 chambers arranged in about 3 whorls. The trochospire is low and consequently the dorsal surface is only slightly convex. The chambers are uniformly inflated but partially embracing and considerably appressed. About 4 chambers are present in the last whorl with the earlier whorls having about 5 chambers. The equatorial profile is sub-circular to ovate and the equatorial periphery is weakly lobulate. The axial profile is sub-oval and the axial periphery smoothly rounded. The umbilicus is very small, almost closed, but depressed. The dorsal sutures are initially obscure but in the last whorl both the spiral and intercameral sutures are slightly depressed and fairly distinct. The later dorsal intercameral sutures are radial, meeting the spiral suture almost at right angles. The ventral sutures are distinct, slightly depressed and nearly radial. The aperture is a long low arch, interiomarginal, umbilical in position, not totally restricted to the deepest part of the umbilical depression. The aperture is bordered by a greatly thickened and broad rim. The test wall is uniformly and finely perforate and is characteristically thick. The test surface is practically smooth with only traces of an original fine hispidity. Maximum diameter of lectotype: 0.31 mm." (Banner and Blow, 1960)

Lectotype: Muséum National de l'Historie Naturelle, Paris, 12309; collection of Alcide d'Orbigny, labelled "Subappenin, Rimini."

*Discussion:* Blow believes that "*Globigerina praebulloides praebulloides* Blow gives rise to *Globigerina bulloides bulloides* within Zone N. 16."

## GLOBIGERINA DRURYI DECORAPERTA Takayanagi and Saito

Pl. 14, fig. 3; Pl. 29, fig. 1;
Pl. 31, fig. 3; Pl. 34, fig. 3;
Pl. 37, fig. 2

*Globigerina druryi* Akers *decoraperta* TAKAYANAGI and SAITO, 1962, Sci. Repts. Tohoku Univ., ser. 2 (Geology), Spec. vol. no. 5, p. 85, pl. 28, fig. 10.

*Globigerina decoraperta* Takayanagi and Saito. PARKER, 1967, Bull. Amer. Paleontology, vol. 52, no. 235, p. 149, pl. 19, figs. 1a-c, not fig. 2.

"Test small, trochospiral, equatorial periphery lobulate, axial periphery broadly rounded; chambers spherical, about 12, arranged in about three whorls, increasing rather rapidly in size, last chamber somewhat protruded in radial direction; sutures rather distinct, depressed, nearly radial on both sides; wall calcareous, perforate, surface pitted; aperture a medium-sized, fairly high, symmetrical arch with a slightly thickened rim, interiomarginal and umbilical in position, placed rightly on opposite sides of

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## PLATE 17
## RED BAY FORMATION ?
## BLOUNT'S CREEK

Figures Page

1. *Globorotalia (Turborotalia) acostaensis acostaensis* Blow. . . . . 106
Maximum diameter, 0.29 mm
a. Umbilical view, X 166
b. Spiral view, X 165

2. *Globorotalia (Globorotalia) cultrata menardii* (Parker, Jones and Brady). . . . . 98
Maximum diameter, 0.40 mm
a. Umbilical view, X 137
b. Spiral view, X 137

3. *Hastigerina (Hastigerina) siphonifera siphonifera* (d'Orbigny). . . . . 124
Maximum diameter, 0.52 mm
a. Spiral view, X 126
b. Peripheral view, X 125

4. *Globorotalia (Turborotalia) acostaensis humerosa* Takayanagi and Saito. . . . . 108
Maximum diameter, 0.36 mm
a. Umbilical view, X 158
b. Spiral view, X 158

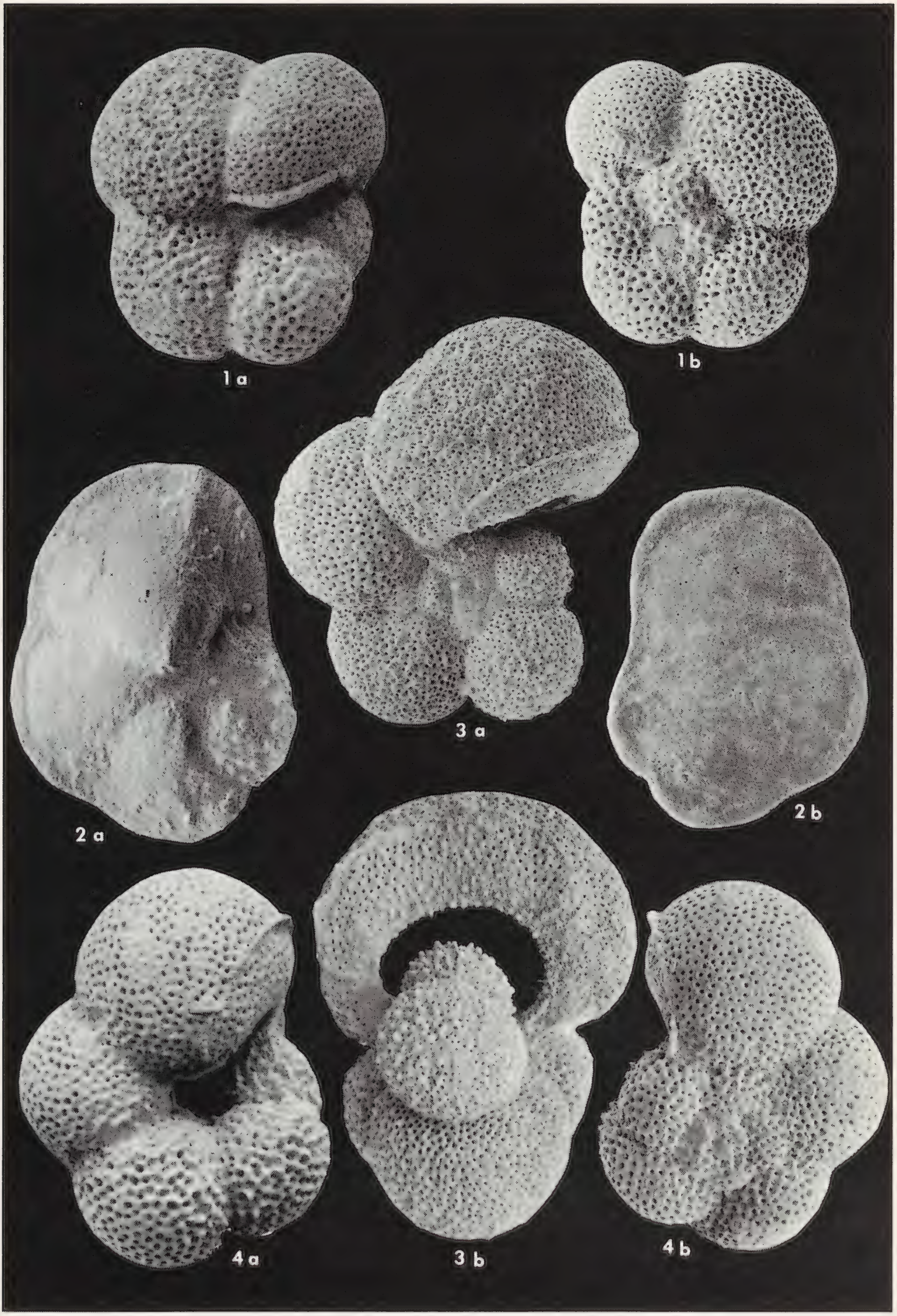


Plate 17

antepenultimate chamber. Coiling of the tests is nearly random, but with slight preference to left in direction. Maximum diameter of holotype 0.26 mm, thickness 0.19 mm. Other specimens range from 0.17 to 0.27 mm in maximum diameter." (Takayanagi and Saito, 1962)

Holotype: IGPS 75070; Nobori Formation, Shikoku, Japan.

*Discussion:* Blow (1969, p. 318) gives Zone N. 14 (? later part Zone N. 13) to Zone N. 21 as the range of this form.

### GLOBIGERINA JUVENILIS Bolli

Pl. 12, fig. 1; Pl. 19, fig. 5;
Pl. 52, fig. 2

*Globigerina juvenilis* BOLLI, 1957, U. S. Natl. Mus., Bull. 215, p. 110, pl. 24, figs. 5a-6.

*Globigerina juvenilis* Bolli. BLOW, 1959, Bull. Amer. Paleontology, vol. 39, no. 178, p. 178, pl. 10, figs. 43a-b.

*Globigerina juvenilis* Bolli. BLOW, 1969, Proc. First International Conference on Planktonic Microfossils, vol. 1, p. 320, pl. 17, figs. 5, 6 (metatype).

"Shape of test moderately to distinctly trochospiral; equatorial periphery distinctly lobate. Wall calcareous, perforate, surface smooth to very finely pitted. Chambers spherical to ovate; about 12, arranged in about 3 whorls; the 3-4 chambers of the last whorl increase rapidly in size. Sutures on spiral side curved to radial in the early stage, radial in the last whorl, depressed; on umbilical side radial, depressed. Umbilicus very small. Aperture a low elongate slit, often with a thin lip; interiomarginal, umbilical. Coiling random. Largest diameter of holotype: 0.29 mm." (Bolli, 1957)

Holotype: USNM P5617; from the type section of the *Globorotalia fohsi robusta* Zone, Trinidad.

*Discussion:* Specimens from Florida compare closely with Blow's specimens from eastern Falcon. Compare his Stereoscan illustrations (Blow, 1969, pl. 17, figs. 5, 6) with those in this report. Relationship is yet to be resolved with *Globigerinita glutinata* (Egger) and *Globigerinita naparimaensis* Bronnimann. The range of *Globigerina juvenilis* is from the base of Zone N. 4 to Zone N. 23 (Blow, 1969).

### GLOBIGERINA NEPENTHES Todd

Pl. 14, fig. 1

*Globigerina nepenthes* TODD, 1957, U. S. Geol. Survey, Prof. Paper 280-H, p. 301, pl. 78, figs. 7a-b.

*Sphaeroidinellopsis nepenthes* (Todd) var. *constricta* BERMÚDEZ, 1961, Mem. III Congr. Geol. Venezolano, vol. 3, Bol. Geol. Publ. esp. 3 (1960), p. 1278, pl. 10, figs. 2a-b.

*Globigerina nepenthes* Todd. POAG and AKERS, 1967, Cushman Found. Foram. Res., Contr. vol. 18, pt. 4, p. 170, pl. 16, figs. 1-12.

*Globigerina nepenthes* Todd. BLOW, 1969, Proc. First International Conference on Planktonic Microfossils, vol. 1, p. 320, pl. 14, fig. 5.

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## PLATE 18
## JACKSON BLUFF FORMATION
## ALUM BLUFF, BED 4

Figures Page

1. *Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny). . . . . 62
Maximum diameter, 0.44 mm
a. Spiral view, X 134
b. Umbilical view, X 133

2. *Globigerinoides obliquus obliquus* Bolli. . . . . 60
Maximum diameter, 0.37 mm
a. Spiral view, X 162
b. Umbilical view, X 162

3. *Globigerinoides ruber* (d'Orbigny). . . . . 66
Maximum diameter, 0.41 mm
a. Spiral view, X 155
b. Umbilical view, X 152

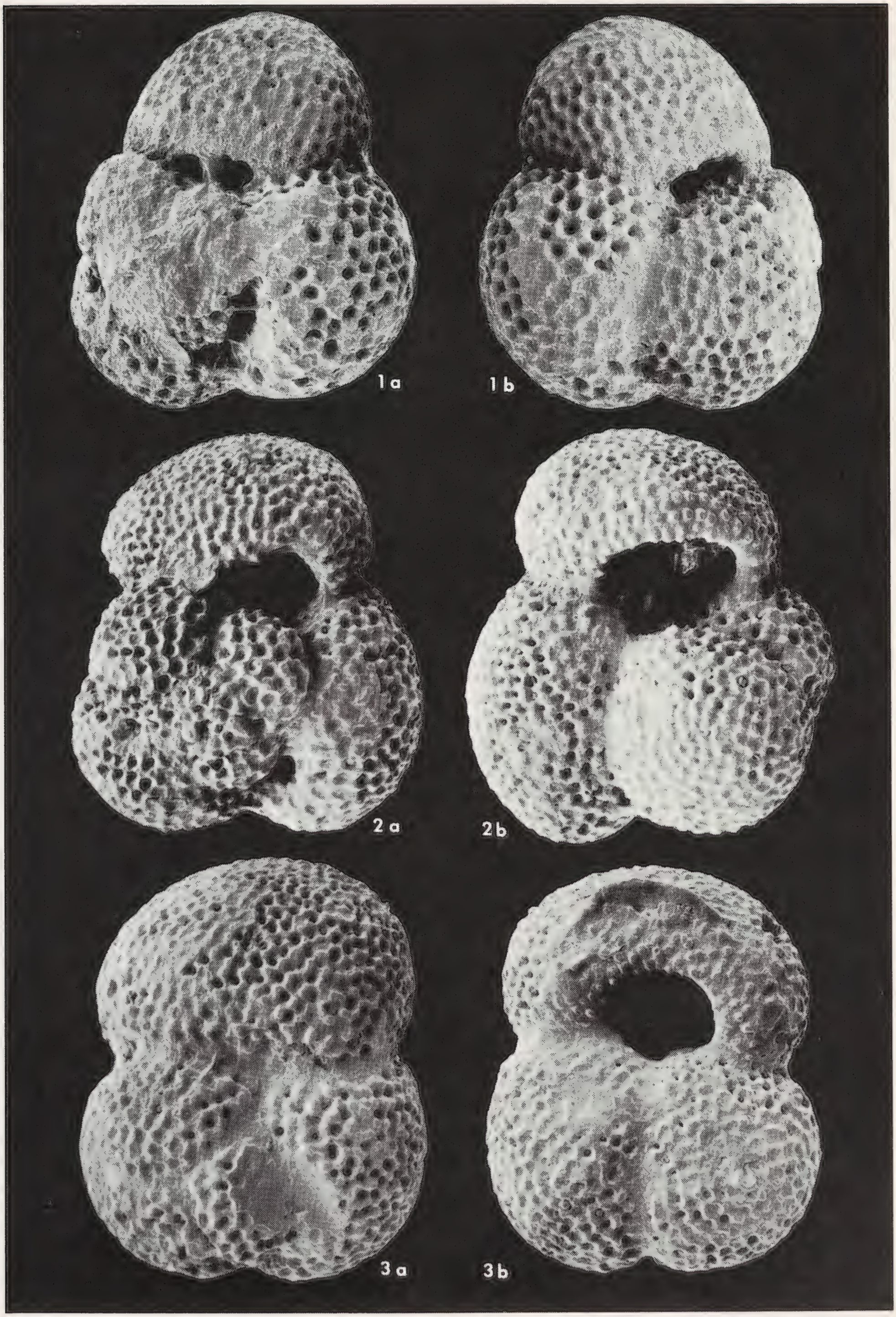


Plate 18

"Test small, compactly coiled except for the last-formed protruding chamber; height of spire ranges between three-quarters of and equal to diameter of spire. Chambers indistinct, slightly inflated; four chambers constituting the last whorl, with a fifth elongate chamber extending downward and at an angle to the axis of coiling. Sutures indistinct, except the last few which are indented. Wall thin, calcareous, perforate, ornamented by a rather coarse cancellation. Aperture large and semi-circular or broad and arched at the umbilical edge of the protruding chamber, bordered by a thickened and slightly upturned lip of clear shell material. Diameter exclusive of protruding chamber 0.30-0.37 mm; greatest dimension of test 0.42-0.58 mm." (Todd, 1957)

Holotype: USNM 624037; Tagpochau Limestone, Donni Sandstone Member, east-central Saipan, Mariana Islands.

*Discussion:* Blow regards the range of this species to be from the base of Zone N. 14 to approximately the boundary between Zones N. 19 and N. 20.

## Genus GLOBIGERINOIDES Cushman, 1927

### GLOBIGERINOIDES BOLLII Blow

Pl. 22, fig. 2; Pl. 48, fig. 2

*Globigerinoides bollii* BLOW, 1959, Bull. Amer. Paleontology, vol. 39 no. 178, pp. 189-191, pl. 10, figs. 65a-c.

*Globigerinoides bollii* Blow. PARKER, 1967, Bull. Amer. Paleontology, vol. 52, no. 235, pp. 153-154, pl. 20, figs. 1, 2.

*Globigerinoides bollii* Blow. BLOW, 1969, Proc. First International Conference on Planktonic Microfossils, vol. 1, p. 324, pl. 20, figs. 2, 3.

"Test trochospiral with four chambers in the last whorl; equatorial periphery lobate; axial periphery rounded; chambers subspherical or ovate, much embracing; sutures of the spiral and umbilical sides depressed but often indistinct, radial to slightly curved; umbilicus small, often almost completely closed; primary aperture interiomarginal, umbilical, the opening almost completely circular but generally rather small; supplementary apertures on the spiral

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PLATE 19
JACKSON BLUFF FORMATION
ALUM BLUFF, BED 4

Figures Page

1. *Globigerina bulloides apertura* Cushman. . . . . 46
Maximum diameter, 0.46 mm
   a. Spiral view, X 133
   b. Umbilical view, X 133

2. *Globorotalia (Globorotalia) multicamerata* Cushman and Jarvis, an immature specimen.
Maximum diameter, 0.28 mm 104
   a. Spiral view, X 157
   b. Umbilical view, X 154

3. *Globorotalia (Turborotalia) acostaensis humerosa* Takayanagi and Saito. . . . . 108
Maximum diameter, 0.44 mm
   a. Spiral view, X 126
   b. Umbilical view, X 127

4. *Globorotalia (Globorotalia) margaritae* Bolli and Bermúdez, an immature specimen. 102
Maximum diameter, 0.35 mm
   a. Spiral view, X 134
   b. Umbilical view, X 133

5. *Globigerina juvenilis* Bolli. . . . . 52
Maximum diameter, 0.42 mm
   a. Spiral view, X 133
   b. Umbilical view, X 133

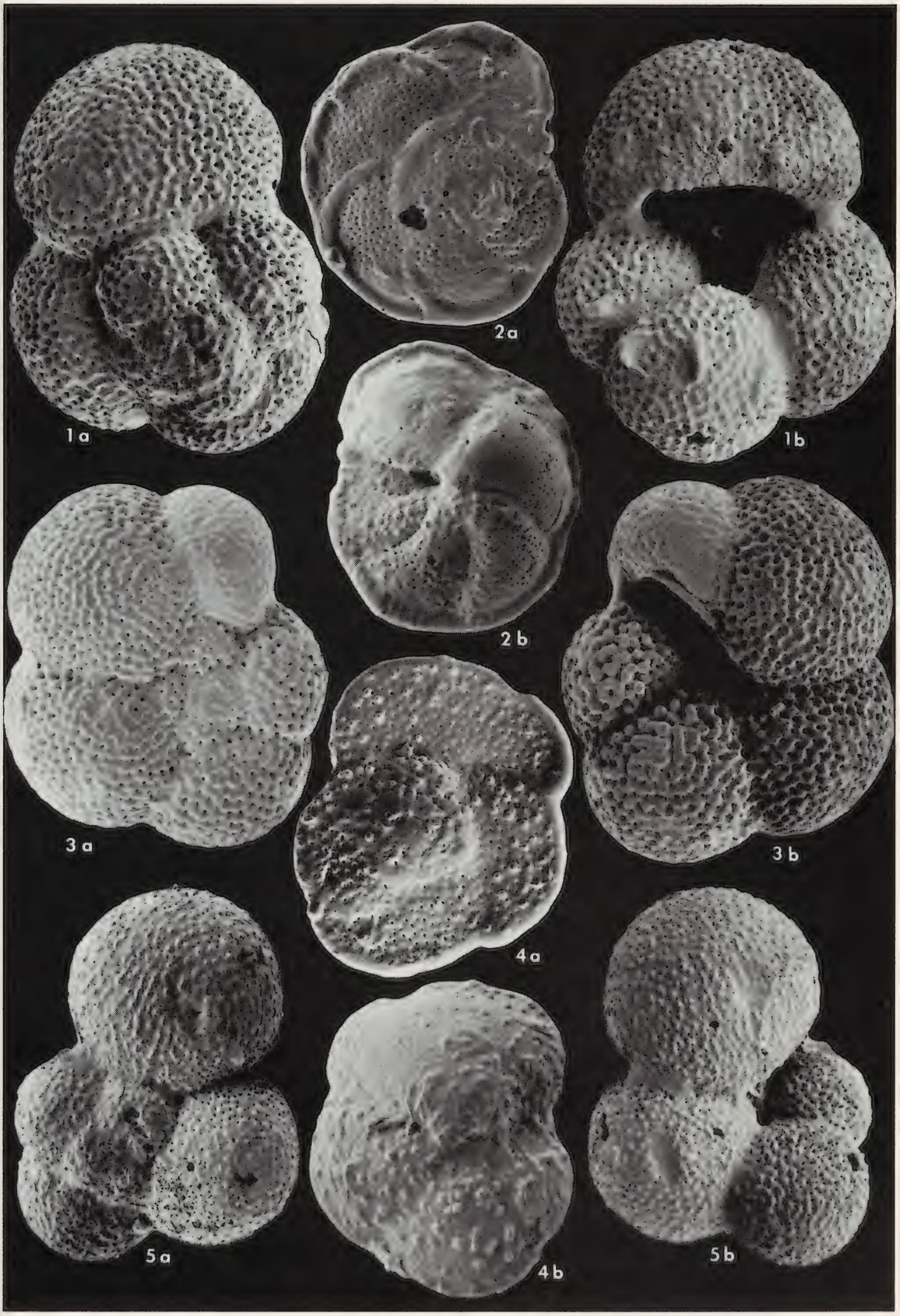


Plate 19

side, sutural, small; usually only one present, situated in the suture between the last chamber and its predecessor, although an additional supplementary aperture may be present in the suture between the penultimate and the antepenultimate chambers; wall calcareous, perforate, often rather thick; maximum diameter of holotype, 0.34 mm." (Blow, 1959)

Holotype: USNM 625717; Pozón Formation, eastern Falcón, Venezuela.

*Discussion:* Specimens from the Blount's Creek site are typical. The range is from "early to middle parts of Zone N. 11 to within Zone N. 21" (Blow, 1969).

## GLOBIGERINOIDES CONGLOBATUS (Brady)

Pl. 24, figs. 1, 2; Pl. 58; figs. 1, 2

*Globigerina conglobata* BRADY, 1879, Quart. Jour. Micr. Science, (new ser.), vol. 19, p. 286.

*Globigerina conglobata* Brady. BRADY, 1884, Rept. Voy. ***Challenger,*** Zoology, vol. 9, p. 603, pl. 80, figs. 1-5; pl. 82, fig. 5.

*Globigerina conglobata* Brady. BANNER and BLOW, 1960, Cushman Found. Foram. Res., Contr., vol. 11, p. 6, pl. 4, fig. 4 (lectotype).

"The shape of the large test is subglobular to subquadrate. In axial profile the dorsal surface is convex and the axial periphery is broadly rounded. The equatorial periphery is weakly lobate. The chambers are coiled in a fairly low but tight trochospire consisting of approximately three whorls. The chambers are initially reniform but later becoming narrowly lunate in dorsal aspect. The later chambers are characteristically strongly depressed, slightly embracing but moderately inflated. There are about 4 1/2 chambers in the earlier whorls reducing to 3 1/2 chambers in the last whorl. The dorsal spiral and intercameral sutures are initially obscure but become distinctly narrowly depressed during ontogeny, so much so that the later formed sutures appear deeply incised and the chambers "bevelled." Four chambers are visible ventrally and the sutures between them are distinct, narrowly depressed, slightly sinuous to radial. The umbilicus is small almost closed, but deep. The apertures are multiple; the distinct primary interiomarginal-umbilical aperture is a fairly long, comparatively low, slightly asymmetric arch broadest posteriorly with respect to the direction of coiling. The dorsal supplementary apertures are sutural in position and are visible in the basal sutures of the chambers of the last whorl and the later part of the penultimate whorl. In the last chamber there are three such supplementary apertures. Both the primary and supplementary apertures of the last chamber are

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## PLATE 20
## JACKSON BLUFF FORMATION
## ALUM BLUFF, BED 4

Figures Page

1. *Globoquadrina altispira globosa* Bolli. . . . . 88
   Maximum diameter, 0.39 mm
   a. Spiral view, X 135
   b. Umbilical view, X 137

2. *Sphaeroidinellopsis subdehiscens subdehiscens* Blow, a decorticated specimen. . . . . 86
   Maximum diameter, 0.39 mm
   a. Spiral view, X 133
   b. Umbilical view, X 133

3. *Sphaeroidinellopsis subdehiscens subdehiscens* Blow. . . . . 86
   Maximum diameter, 0.45 mm
   a. Spiral view, X 126
   b. Umbilical view, X 125

4. *Sphaeroidinellopsis subdehiscens subdehiscens* Blow, a decorticated specimen. . . . . 86
   Maximum diameter, 0.52 mm
   a. Spiral view, X 134
   b. Umbilical view, X 133

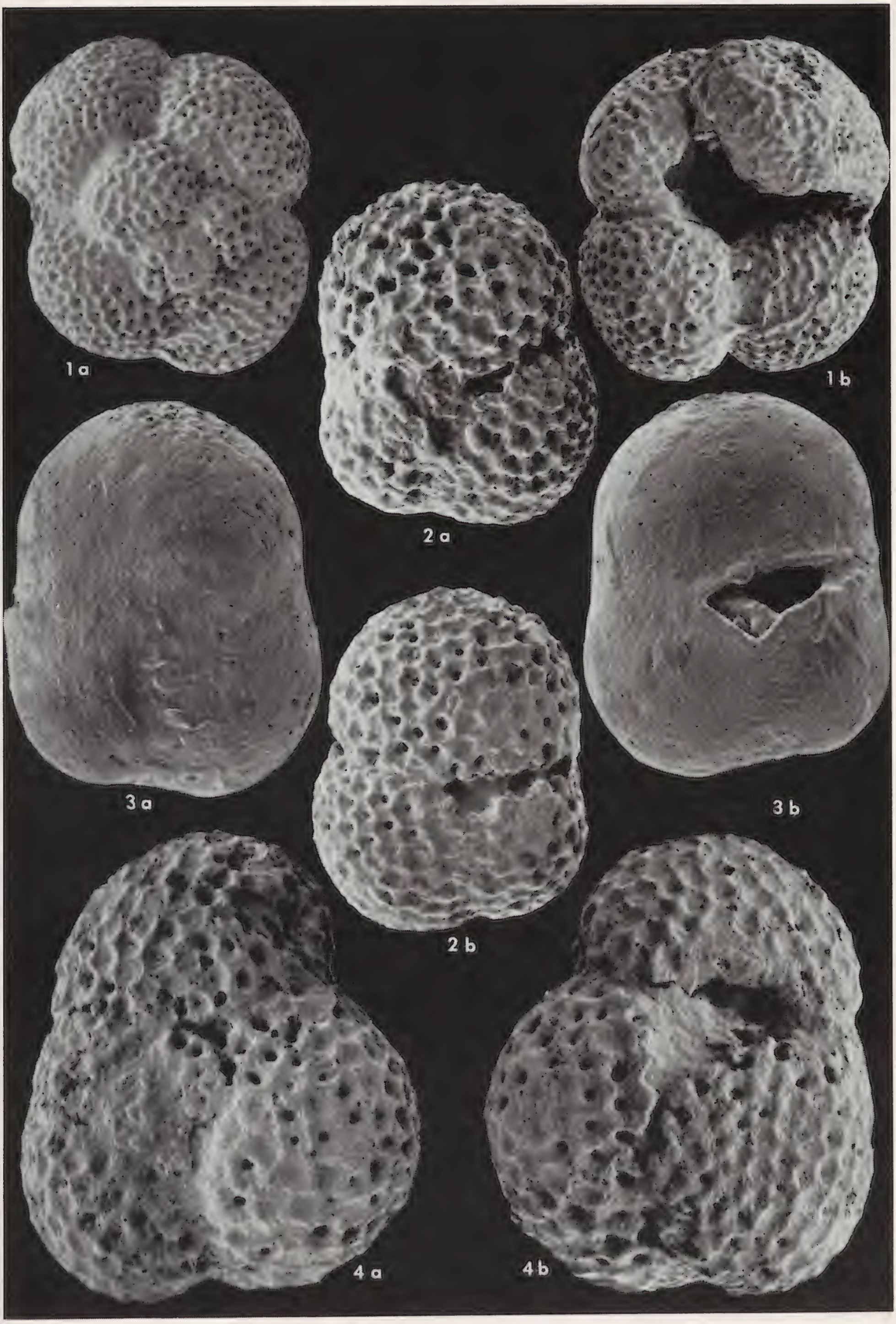


Plate 20

bordered by thickened rim-like lips. The wall is characteristically very thick, especially in the early whorls, and it is uniformly and fairly coarsely perforate. The surface of the test is cancellate and syntypes taken *in vivo* show it to have been originally finely, uniformly and densely spinose. Maximum diameter of lectotype: 0.85 mm." (Banner and Blow, 1960)

Lectotype: British Museum (Natural History) 1959.4.13.7; obtained by Brady from *Challenger* station 338, S. Atlantic, at 1990 fathoms.

*Discussion:* Forms from Watson's Landing are identical with specimens from the Bowden beds of Jamaica (Palmer, 1945, p. 6, Station 2). *G. conglobatus conglobatus* is rare in the writer's material from both Bowden and Watson's Landing. It is characteristic of the specimens from these two localities that the later chambers are not so depressed as in specimens from modern seas. In these fossil forms the primary aperture is usually infilled causing it to appear smaller and sutural in position. This results in a superficial resemblance to *Globigerinoides gomitulus* (Seguenza) for which *Globigerinoides cyclostomata* (Galloway and Wissler) appears to be a junior synonym. *G. gomitulus* is a smaller form, and it has a larger, higher aperture than *G. conglobatus conglobatus*. Mamelones and a confluence of pore ridges seen on the specimens from Watson's Landing (pl. 24, figs. 1, 2) are also characteristic of some specimens from Recent sediments, and the development of these wall structures appears to be an ecological function (bathymetry?). The compact, closely coiled test of the Florida and Bowden forms is typical of *G. conglobatus conglobatus*.

The range of this subspecies is from within Zone N. 17 to Zone N. 23, according to Blow.

## GLOBIGERINOIDES OBLIQUUS EXTREMUS Bolli and Bermúdez

Pl. 23, fig. 2; Pl. 38, fig. 1;
Pl. 43, fig. 1; Pl. 48, fig. 3

*Globigerinoides obliquus extremus* BOLLI and BERMÚDEZ, 1965, Bol. Informativo, Assoc. Venezolana de Geol., Min. y Pet., vol. 8 no. 5, p. 139, pl. 1, figs. 10-12.

*Globigerinoides obliquus extremus* Bolli and Bermúdez. BLOW, 1969, Proc. First International Conference on Planktonic Microfossils, vol. 1, p. 324, pl. 21, figs. 2, 3.

"Shape of test high trochospiral; equatorial periphery distinctly lobate; axial periphery rounded. Wall calcareous, perforate, surface finely pitted.

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## PLATE 21
## JACKSON BLUFF FORMATION ?
## WATSON'S LANDING

Figures

Page

1. *Globigerina* sp. . . . . 16
Maximum diameter, 0.36 mm
a. Edge view, X 154
b. Spiral view, X 157
c. Umbilical view, X 155

2. *Globigerinita glutinata* (Egger). . . . . 70
Maximum diameter, 0.29 mm
a. Spiral view, X 167
b. Umbilical view, X 167
c. Edge view, X 167

3. *Globigerina bulloides apertura* Cushman. . . . . 46
Maximum diameter, 0.40 mm
a. Edge view, X 147
b. Spiral view, X 143
c. Umbilical view, X 147

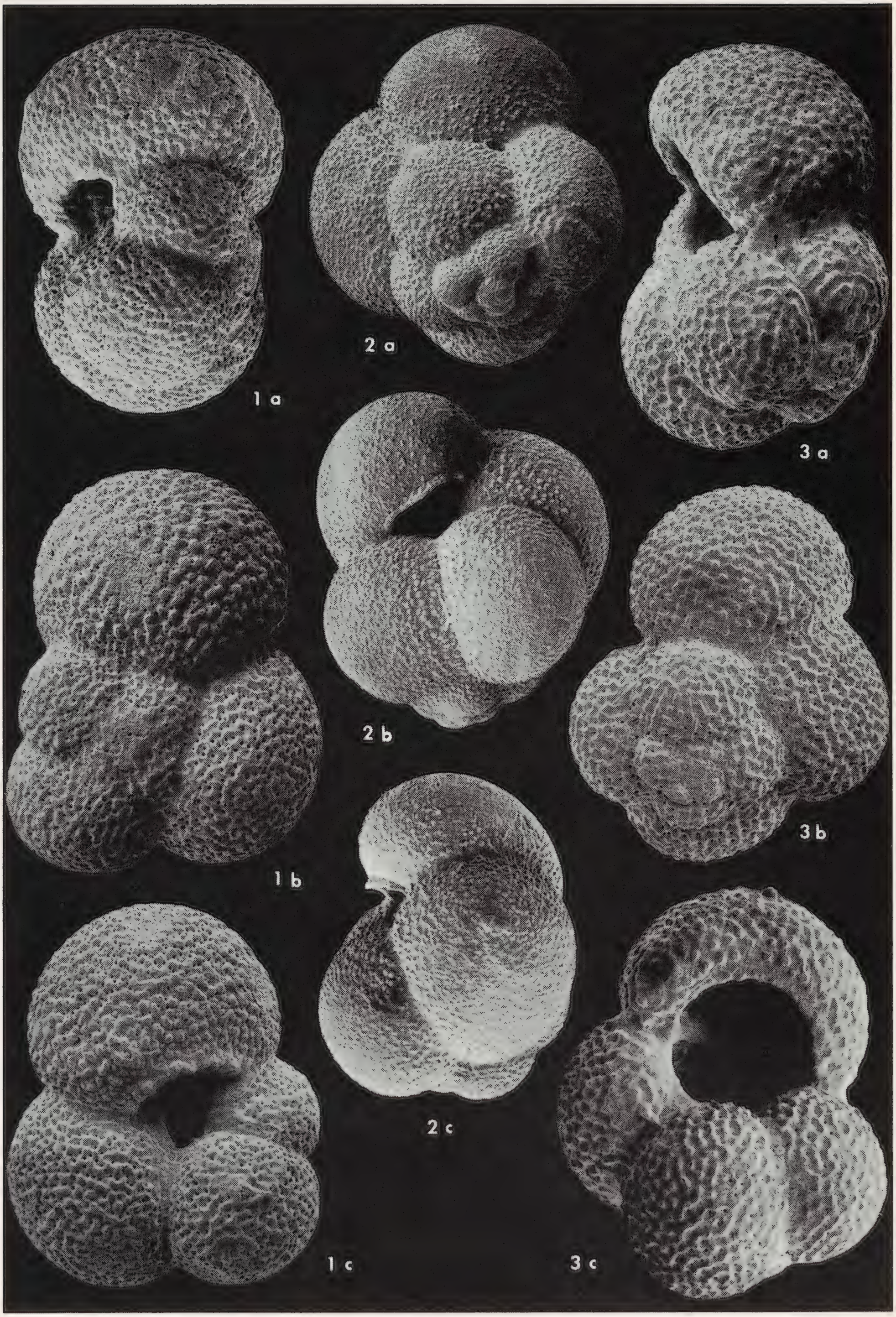


Plate 21

Chambers of the last whorl progressively more compressed in a lateral, oblique manner; 10-12, arranged in 2 to 3 whorls; the last 4 chambers of the last whorl increase fairly rapidly in size, though the last chamber may be slightly reduced in some specimens. Sutures somewhat oblique on spiral and umbilical side, incised. Umbilicus rather narrow. Primary aperture a distinct arch of medium height, interiomarginal, umbilical. One supplementary aperture on last chamber often also visible on earlier ones. Largest diameter of holotype: 0.36 mm." (Bolli and Bermúdez, 1965)

Holotype: USNM; from core 1029-1034 feet, Cubagua-1, Estado Nueva Esparta, Venezuela.

*Discussion:* This form ranges from the earlier part of Zone N. 16 to within Zone N. 21, according to Blow.

## GLOBIGERINOIDES OBLIQUUS OBLIQUUS Bolli

Pl. 7, fig. 1; Pl. 10, fig. 1;
Pl. 16, fig. 1; Pl. 18, fig. 2;
Pl. 26, fig. 2; Pl. 27, fig. 3;
Pl. 35, fig. 1; Pl. 53, fig. 2;
Pl. 56, fig. 1; Pl. 58, fig. 3

*Globigerinoides obliqua* BOLLI, 1957, U. S. Natl. Mus., Bull. 215, p. 113, pl. 25, figs. 9, 10; text-fig. 21, no. 5.

*Globigerinoides obliquus obliquus* Bolli. BLOW, 1969, Proc. First International Conference on Planktonic Microfossils, vol. 1, p. 324.

"Shape of test trochospiral; equatorial periphery distinctly lobate; axial periphery rounded. Wall calcareous, perforate, surface finely pitted. Chambers spherical, except the ultimate ones, which are compressed in a lateral oblique manner; chambers twelve to fifteen, arranged in about three whorls; the three, in large specimens four, chambers of the last whorl increase rapidly in size; in large specimens the last chamber may be reduced again in size. Sutures on spiral side radial to oblique, depressed; on umbilical side radial, depressed. Umbilicus small. Primary aperture a distinct, often fairly high arch, interiomarginal, umbilical; one or occasionally two supplementary sutural apertures are visible in the last few chambers. Largest diameter of holotype, 0.5 mm." (Bolli, 1957)

Holotype: USNM P5634; Lengua Formation, 2½ miles south-southeast of Lengua Settlement, southern Trinidad.

*Discussion:* The range, according to Blow is from the latest part of Zone N. 5 into Zone N. 22.

## GLOBIGERINOIDES QUADRILOBATUS ALTIAPERTURUS Bolli

*Globigerinoides triloba altiapertura* BOLLI, 1957, U. S. Natl. Mus., Bull. 215, p. 113, pl. 25, figs. 7a-8.

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## PLATE 22
## JACKSON BLUFF FORMATION ?
## WATSON'S LANDING

Figures Page

1. *Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny). . . . . 62
Maximum diameter, 0.59 mm
   a. Edge view, X 97
   b. Spiral view, X 103
   c. Umbilical view, X 98

2. *Globigerinoides bollii* Blow. . . . . 54
Maximum diameter, 0.28 mm
   a. Spiral view, X 183
   b. Umbilical view, X 182
   c. Edge view, X 182

3. *Globigerinoides ruber* (d'Orbigny). . . . . 66
Maximum diameter, 0.44 mm
   a. Umbilical view, X 129
   b. Edge view, X 133
   c. Spiral view, X 136

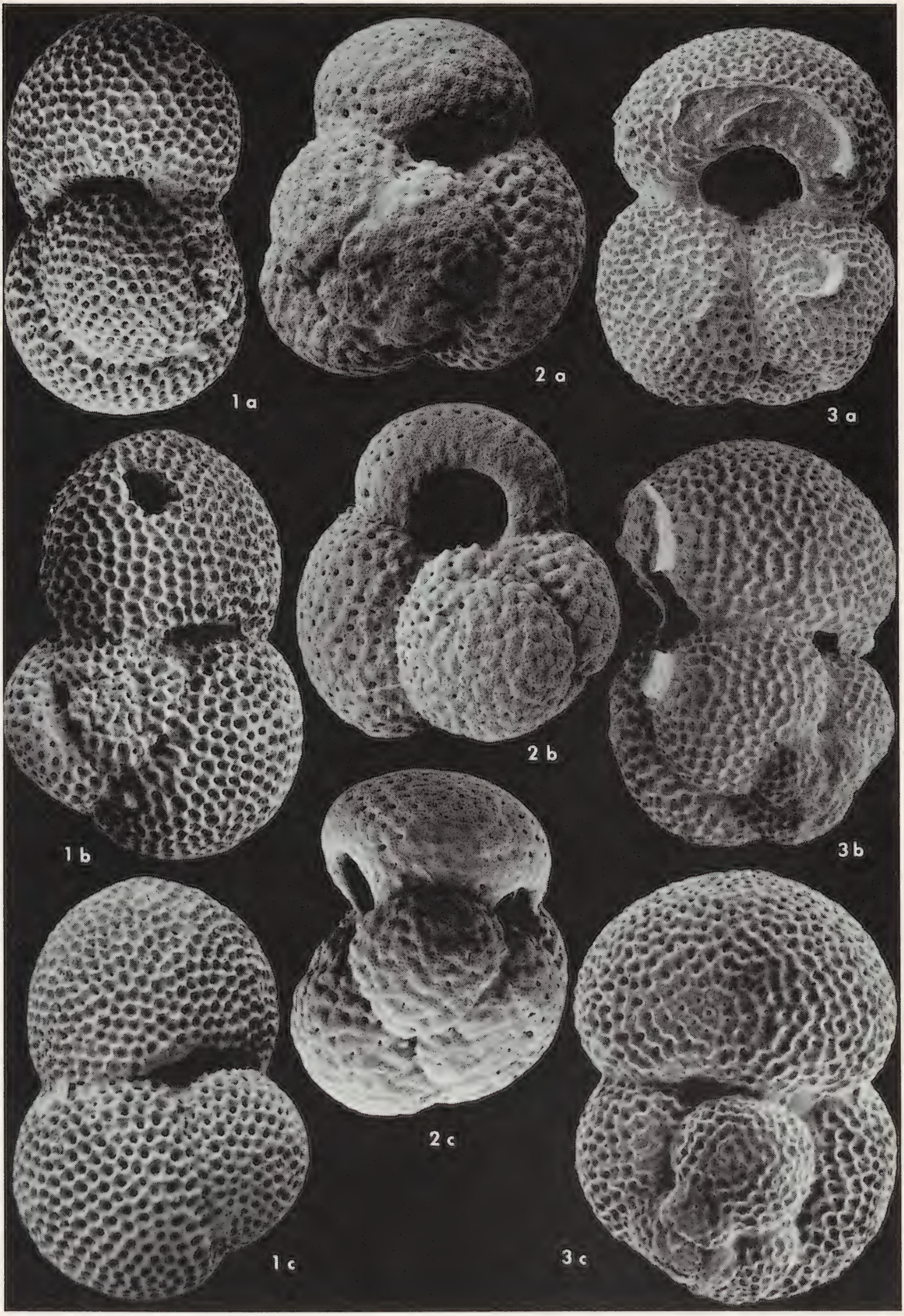


Plate 22

*Globigerinoides triloba altiapertura* Bolli. BLOW, 1959, Bull. Amer. Paleontology, vol. 39, no. 178, pp. 187-188, pl. 10, figs. 61 a-b.
*Globigerinoides quadrilobatus altiaperturus* Bolli. BLOW, 1969, Proc. First International Conference on Planktonic Microfossils, vol. 1, p. 325.

"Shape of test trochospiral; equatorial periphery distinctly lobate (trilobate); axial periphery rounded. Wall calcareous, perforate, surface finely pitted. Chambers spherical; about twelve, arranged in about two and one-half whorls; the three chambers of the last whorl increase rapidly in size. Sutures on spiral side between early chambers radial, later slightly curved and oblique, depressed; on the umbilical side radial, depressed. Umbilicus fairly narrow, deep. Primary aperture a high, distinct arch, interiomarginal, umbilical; the last few chambers show one supplementary sutural aperture about opposite the primary aperture. Coiling random. Largest diameter of holotype, 0.55 mm." (Bolli, 1957)

Holotype: USNM P5632; Cipero Formation, western Trinidad.

*Discussion:* This form ranges from near the base of Zone N. 5 to within the earlier parts of Zone N. 7, according to Blow. Specimens from the Chipola Formation have a wider primary aperture than do specimens from the Cipero Formation.

## GLOBIGERINOIDES QUADRILOBATUS QUADRILOBATUS (d'Orbigny)

Pl. 3, fig. 4; Pl. 6, fig. 2;
Pl. 11, figs. 2, 3; Pl. 16, fig. 4;
Pl. 18, fig. 1; Pl. 22, fig. 1;
Pl. 27, fig. 2; Pl. 30, fig. 3;
Pl. 34, fig. 4; Pl. 39, fig. 2;
Pl. 42, fig. 3; Pl. 49, fig. 1;
Pl. 53, fig. 3; Pl. 56, fig. 2;
Pl. 59, fig. 1

*Globigerina quadrilobata* D'ORBIGNY, 1846, Foraminifères fossiles du bassin tertiaire de Vienne, p. 164, pl. 9, figs. 7-10.
*Globigerina quadrilobatus* d'Orbigny. BANNER and BLOW, 1960, Cushman Found. Foram. Res., Contr., vol. 11, pp. 17-19, pl. 4, figs. 3a-b (lectotype).
*Globigerinoides quadrilobatus quadrilobatus* d'Orbigny. BLOW, 1969, Proc. First International Conference on Planktonic Microfossils, vol. 1, p. 35.

"The fairly large test consists of about nine chambers arranged in a low, loose trochospire of about two whorls, each whorl, following the proloculum, consisting of about four chambers. The chambers are rapidly and uniformly enlarging, much inflated and little embracing. The equatorial profile is ovoid and the test has a strongly lobulate equatorial periphery. The axial profile is ovate and the axial periphery is smoothly rounded. The chambers are sub-globular and the intercameral sutures become increasingly deeply depressed during ontogeny. The spiral suture is initially slightly depressed becoming deeply depressed and incised in the last whorl. The umbilicus is small, almost closed, and is shallow. The apertures are multiple; the primary aperture is interiomarginal, umbilical, a low, symmetrical, sub-rectangular arch-like opening with no lip or rim. The dorsal supplementary apertures open in the spiral suture; each is an elongate, rather slit-like opening present at the base of each chamber in the last whorl at least and they may be present in the earlier whorls. The supplementary apertures do not possess lips or well marked rims. The wall is

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## PLATE 23
## JACKSON BLUFF FORMATION ?
## WATSON'S LANDING

Figures Page

1. *Globigerinoides ruber* (d'Orbigny). . . . . 66
Maximum diameter, 0.47 mm
   a. Side view, X 126
   b. Umbilical view, X 126
   c. Spiral view, X 127

2. *Globigerinoides obliquus extremus* Bolli and Bermúdez. . . . . 58
Maximum diameter, 0.39 mm
   a. Edge view, X 143
   b. Spiral view, X 143
   c. Umbilical view, X 145

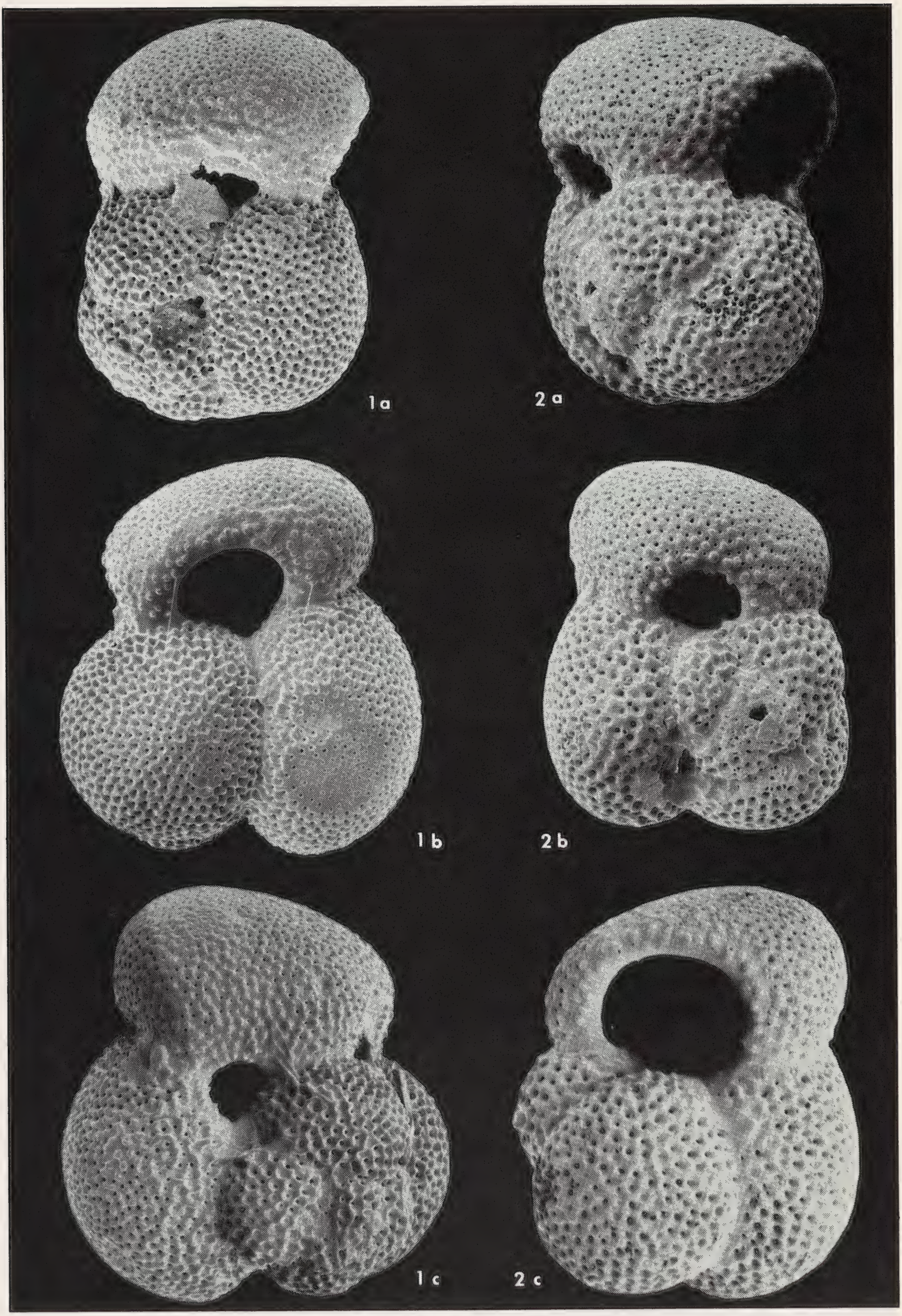


Plate 23

thick, and is coarsely uniformly perforate. The surface of the test is markedly cancellate and punctate. Maximum diameter of lectotype: 0.57 mm." (Banner and Blow, 1960)

Lectotype: Muséum National de l'Histoire Naturelle, Paris; selected from specimens which bore the label "*Globigerina quadrilobata* d'Orbigny, Tortonien, Nussdorf (Autriche)."

*Discussion:* Banner and Blow (1960) and Parker (1967) thoroughly discuss the taxonomic problem relating to this form and those forms described as *Globigerina triloba* Reuss 1850, *Globigerina sacculifera* Brady 1879, *Globigerinoides sacculiferus* (Brady) var. *immatura* LeRoy 1939, and *Sphaeroidinella cellata* Subbotina 1958. This problem is further complicated by the shallow paleobathymetry indicated for the sediments studied for the present report, since there is a possible ecotypic relationship between bathyal to abyssal depths and the elongate sac-like final chamber observed on specimens of this plexus, particularly those of late Miocene and younger age. Specimens close in appearance to the lectotype (without a sac-like final chamber and with a high primary aperture) are the predominant planktonic foraminifers at all of the Chipola localities included in this study. Blow (1969, p. 325) considers the range of *Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny) to be from near the top of Zone N. 4 to Zone N. 23.

## GLOBIGERINOIDES QUADRILOBATUS SACCULIFER (Brady)

Pl. 59, fig. 2

*Globigerina sacculifera* BRADY, 1877, Geol. Mag., (new ser.), Decade 2, vol. 4, no. 12, p. 535.

*Globigerina sacculifera* Brady. BRADY, 1879, Quart. Jour. Micr. Sci., (new ser.), vol. 19, p. 287.

*Globigerina sacculifera* Brady. BRADY, 1884, Rept. Voy. *Challenger,* Zoology, vol. 9, p. 604, pl. 80, figs. 11-17; pl. 82, fig. 4 (these figured specimens are from oceanic surface sediments and plankton).

*Globigerina sacculifera* Brady. BANNER and BLOW, 1960, Cushman Found. Foram. Res., Contr., vol. 11, p. 21, pl. 4, figs. 1 (lectotype), 2.

"The large, sub-tetrahedroid test consists of about 2 1/2 whorls of ovoid, inflated chambers arranged 3 1/2 to 4 in each convolution of a low trochospire. The equatorial profile is sub-triangular and the equatorial periphery is lobulate. The axial profile is also sub-triangular but approaches an oval shape. The axial periphery is broadly rounded on the earlier chambers, becoming narrowly rounded over the last chamber. All chambers except the last are constant in shape and are regularly enlarging; the last chamber is "sac-like," and differs but little from the volume of the penultimate chamber although it is of

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## PLATE 24
## JACKSON BLUFF FORMATION ?
## WATSON'S LANDING

Figures Page

1. *Globigerinoides conglobatus conglobatus* (Brady). . . . . 56
Maximum diameter, 0.56 mm
   a. Spiral view, X 93
   b. Edge view, X 92
   c. Umbilical view, X 92

2. *Globigerinoides conglobatus conglobatus* (Brady). . . . . 56
Maximum diameter, 0.46 mm
   a. Spiral view, X 121
   b. Umbilical view, X 122

3. *Hastigerina (Hastigerina) siphonifera siphonifera* (d'Orbigny). . . . . 124
Maximum diameter, 0.57 mm
   a. Spiral view, X 103
   b. Edge view, X 101
   c. Umbilical view, X 101

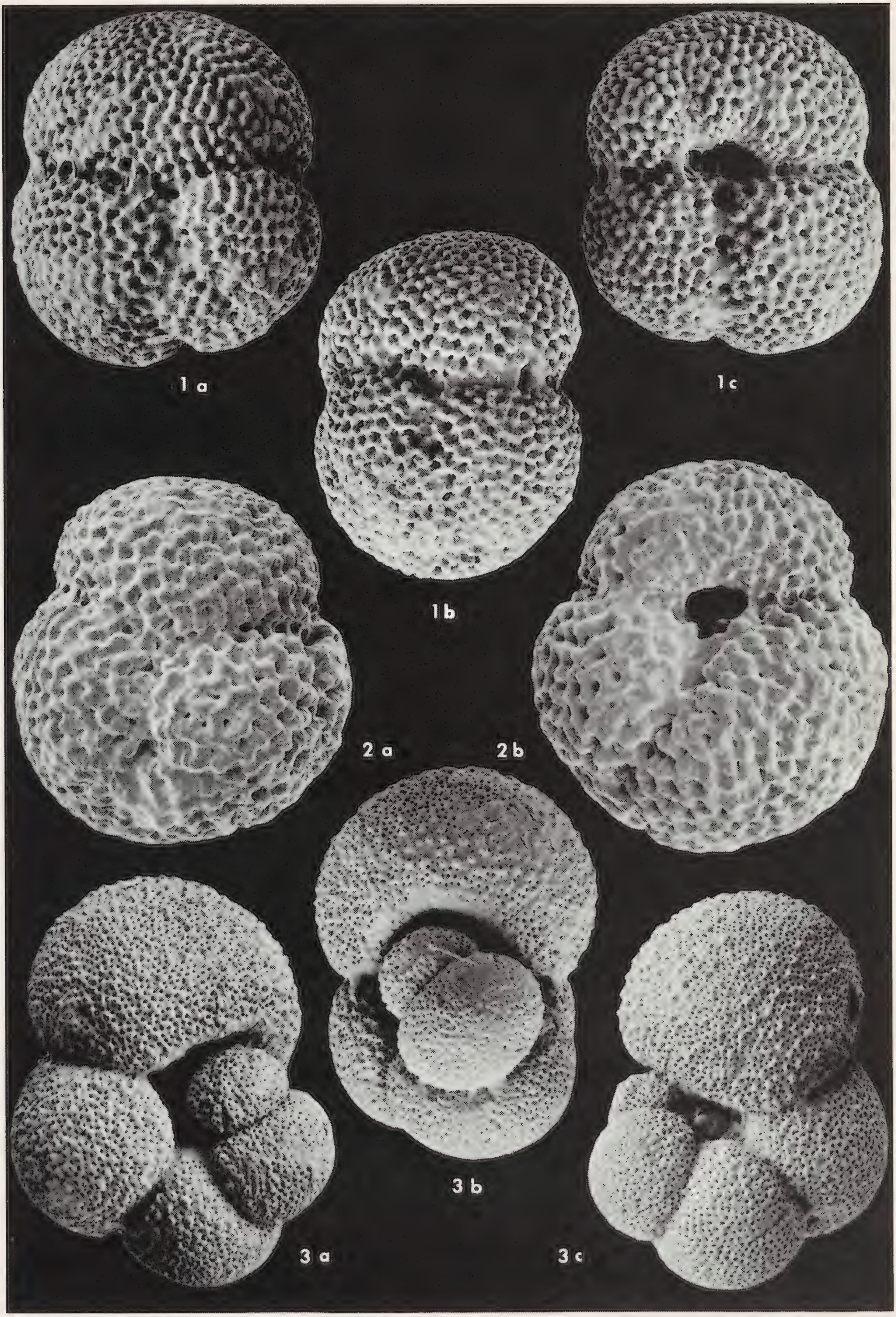


Plate 24

distinctly different shape. The sutures are slightly and broadly depressed, the intercameral sutures are distinctly curved dorsally, meeting the lobulate spiral suture at almost right angles. The ventral intercameral sutures are slightly sinuous to nearly radial. The umbilicus is small, almost but not totally closed, and is shallow. The apertures are multiple; the primary aperture is interiomarginal, intra-umbilical, a moderately low, almost semicircular, slightly asymmetrical arch, with no rim or lip visible. The dorsal supplementary apertures are situated at the base of the chambers, opening in the spiral suture; they are low, virtually semicircular arches with no lips or rims and appear to be present from at least the beginning of the last whorl. Only one supplementary aperture is present in each chamber. The wall is fairly thick and is uniformly and coarsely perforate. The surface of the test is cancellate but with little trace of any original hispidity. Maximum diameter of lectotype: 0.56 mm." (Banner and Blow, 1960)

Lectotype: British Museum (Natural History) P.44033; obtained from an exotic block (of upper Miocene or Pliocene age?) from New Ireland.

*Discussion:* The form, as understood in collections from the Moín Formation, ranges from Zone N. 6 to Zone N. 23.

GLOBIGERINOIDES RUBER (d'Orbigny)

Pl. 16, fig. 3; Pl. 18, fig. 3;
Pl. 22, fig. 3; Pl. 23, fig. 1;
Pl. 26, fig. 4; Pl. 27, fig. 1;
Pl. 35, fig. 2; Pl. 38, fig. 3;
Pl. 43, fig. 2; Pl. 49, fig. 2;
Pl. 53, fig. 1; Pl. 56, fig. 3;
Pl. 58, fig. 4

*Globigerina rubra* D'ORBIGNY *in* DE LA SAGRA, 1839, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 82, pl. 4, figs. 12-14.

*Globigerina rubra* d'Orbigny. BANNER and BLOW, 1960, Cushman Found. Foram. Res., Contr., vol. 11, p. 19, pl. 3, fig. 8 (lectotype).

*Globigerinoides ruber* (d'Orbigny). CORDEY, 1967, Palaeontology, vol. 10, pt.4, pp. 647-659, pl. 103, figs. 7-14, text-fig. 1a-d, text-fig. 3 (figs. 3a-5b).

*Globigerinoides ruber* (d'Orbigny). BLOW, 1969, Proc. First International Conference on Planktonic Microfossils, vol. 1, p. 326, pl. 21, figs. 4, 7.

"The fairly large test consists of slightly more than two whorls of strongly inflated chambers arranged three to a whorl in a moderately high trochospire. The equatorial profile is subovate, but the equatorial periphery is strong lobulate. The dorsal surface is distinctly convex and the earlier whorls are clearly visible. The chambers are subglobular to sub-ovoid and are broadly reniform in dorsal aspect, well separated one from the other and are but little embracing. The sutures are distinctly and broadly depressed both dorsally and ventrally; they are strongly curved dorsally, but also radial ventrally. The apertures are multiple. The primary aperture is interiomarginal umbilical, a moderately high, semicircular arch bordered by a distinct, uniformly narrow, rim; the primary aperture is placed and shaped symmetrically with respect to the intercameral suture between the penultimate and antepenultimate chambers. The supplementary apertures are dorsal in position and are situated at the basal suture of each chamber at its junction with the adjacent intercameral suture of the preceding whorl. One or two such supplementary apertures are present in each chamber of the last whrol. The supplementary apertures are high, semicircular arches, with very thin rims. The umbilicus is small, almost closed and very shallow. The wall is calcareous, apparently radial in structure, uniformly

## PLATE 25
## JACKSON BLUFF FORMATION ?
## WATSON'S LANDING

Figures Page

1. *Globoquadrina altispira globosa* Bolli. . . . . 88
   Maximum diameter, 0.41 mm
   a. Spiral view, X 147
   b. Edge view, X 129
   c. Umbilical view, X 137

2. *Globorotalia (Turborotalia) acostaensis humerosa* Takayanagi and Saito. . . . . 108
   Maximum diameter, 0.50 mm
   a. Spiral view, X 126
   b. Edge view, X 126
   c. Umbilical view, X 126

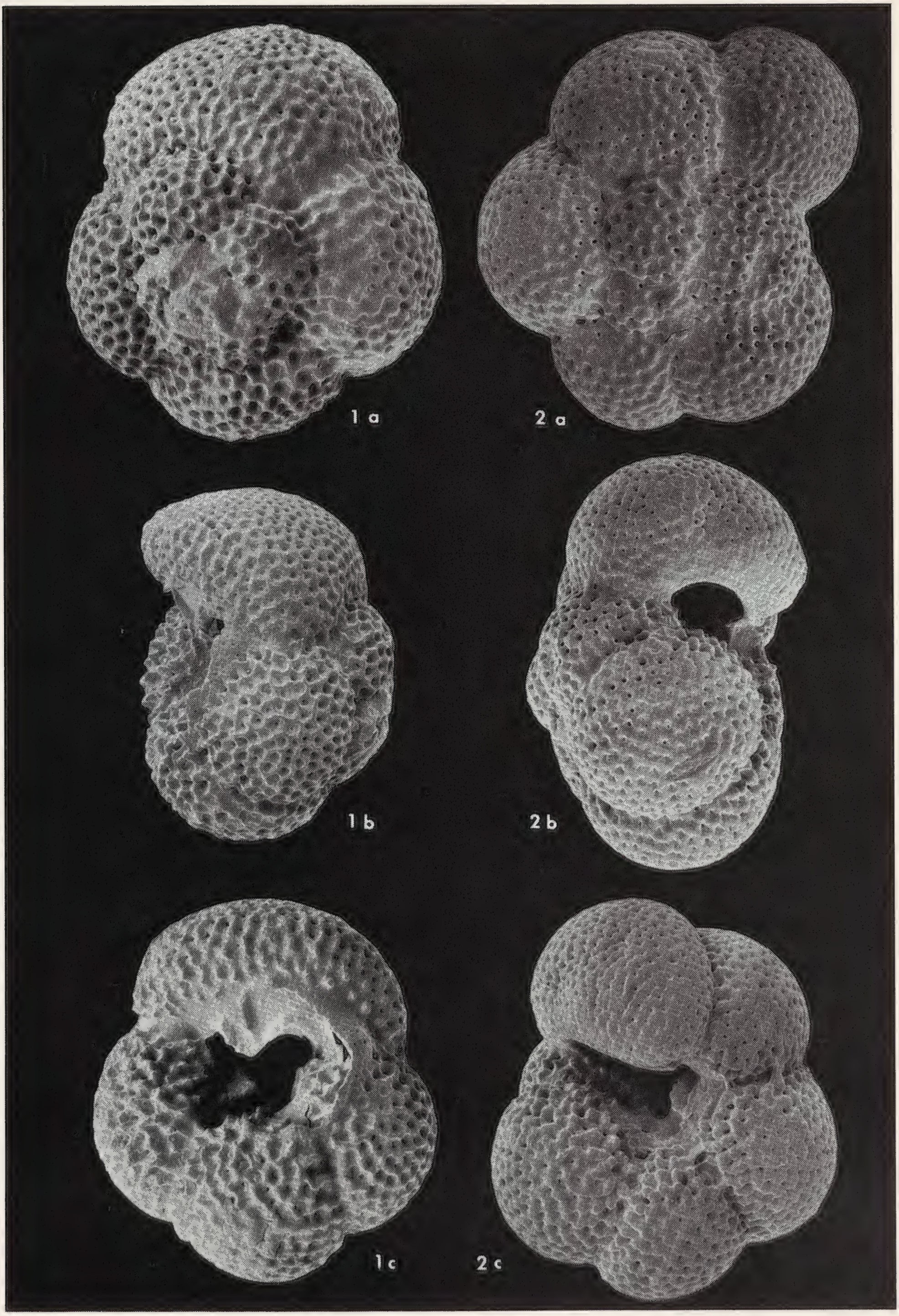


Plate 25

and fairly finely perforate and moderately thin. The surface of the test is slightly rough, but little trace of any original hispidity exists in the lectotype. The earlier part of the test is red coloured, not with the red tint of ferric compounds, but with a deeper and more crimson hue, probably of an organic origin. Maximum diameter of lectotype: 0.62 mm." (Banner and Blow, 1960)

Lectotype: d'Orbigny Collection, Muséum National de l'Histoire Naturelle, Paris; Recent deposits of Cuba.

*Discussion:* Blow agrees with Cordey in the separation of this species from *Globigerinoides subquadratus* Bronnimann. See his description of *G. subquadratus* (this report). Blow considers the range of *G. ruber* to be from the middle part of Zone N. 16 to Zone N. 23.

## GLOBIGERINOIDES SUBQUADRATUS Bronnimann

Pl. 4, fig. 3

*Globigerinoides subquadratus* BRONNIMANN *in* TODD, CLOUD, LOW, and SCHMIDT, 1954, Amer. Jour. Sci., vol. 252, p. 680, pl. 1, fig. 5.

*Globigerinoides rubra* d'Orbigny. BOLLI, 1957, U. S. Natl. Mus., Bull. 215, p. 113, pl. 25, figs. 12a-13b, text-fig. 21, no. 6.

*Globigerinoides subquadratus* Bronnimann. CORDEY, 1967, Palaeontology, vol. 10, pt. 4, pp. 650-651, pl. 103, figs. 1a, 2a, b-4; text-fig. 1e-h; text-fig. 2 (4a-6c).

*Globigerinoides subquadratus* Bronnimann. BLOW, 1969, Proc. First International Conference on Planktonic Microfossils, vol. 1, pp. 326-327, pl. 21, figs. 5, 6.

"Test moderately large, consisting of proloculus followed by whorl of four or possibly five chambers, a second (or penultimate) whorl of four chambers gradually and uniformly increasing in size and a final whorl of three chambers. Periphery varies from lobulate to quadrate in outline. Primary aperture usually large, interiomarginal, umbilical, and situated symmetrically with respect to the penultimate and antepenultimate chambers. Two dorsal supplementary apertures are present at the base of the final chamber, and one at the junction of the basal suture and the intercameral suture of the preceding whorl. Umbilicus shallow. Wall radiate calcareous, frequently thickened, with a slightly rugose surface.

"The essential difference between *G. subquadratus* and *G. ruber* is in their ontogeny. The former has a penultimate whorl of four chambers, while the

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## PLATE 26
## JACKSON BLUFF FORMATION ?
## DARLING SLIDE, UPPER HORIZON

Figures Page

1. *Hastigerina (Hastigerina) siphonifera siphonifera* (d'Orbigny). . . . . 124
Maximum diameter, 0.44 mm
a. Spiral view, X 126
b. Edge view, X 127

2. *Globigerinoides obliquus obliquus* Bolli. . . . . 60
Maximum diameter, 0.35 mm
a. Spiral view, X 133
b. Umbilical view, X 136

3. *Globorotalia (Turborotalia) acostaensis humerosa* Takayanagi and Saito. . . . . 108
Maximum diameter, 0.48 mm
a. Spiral view, X 126
b. Umbilical view, X 126
c. Edge view, X 126

4. *Globigerinoides ruber* (d'Orbigny). . . . . 66
Maximum diameter, 0.39 mm
a. Spiral view, X 140
b. Umbilical view, X 136

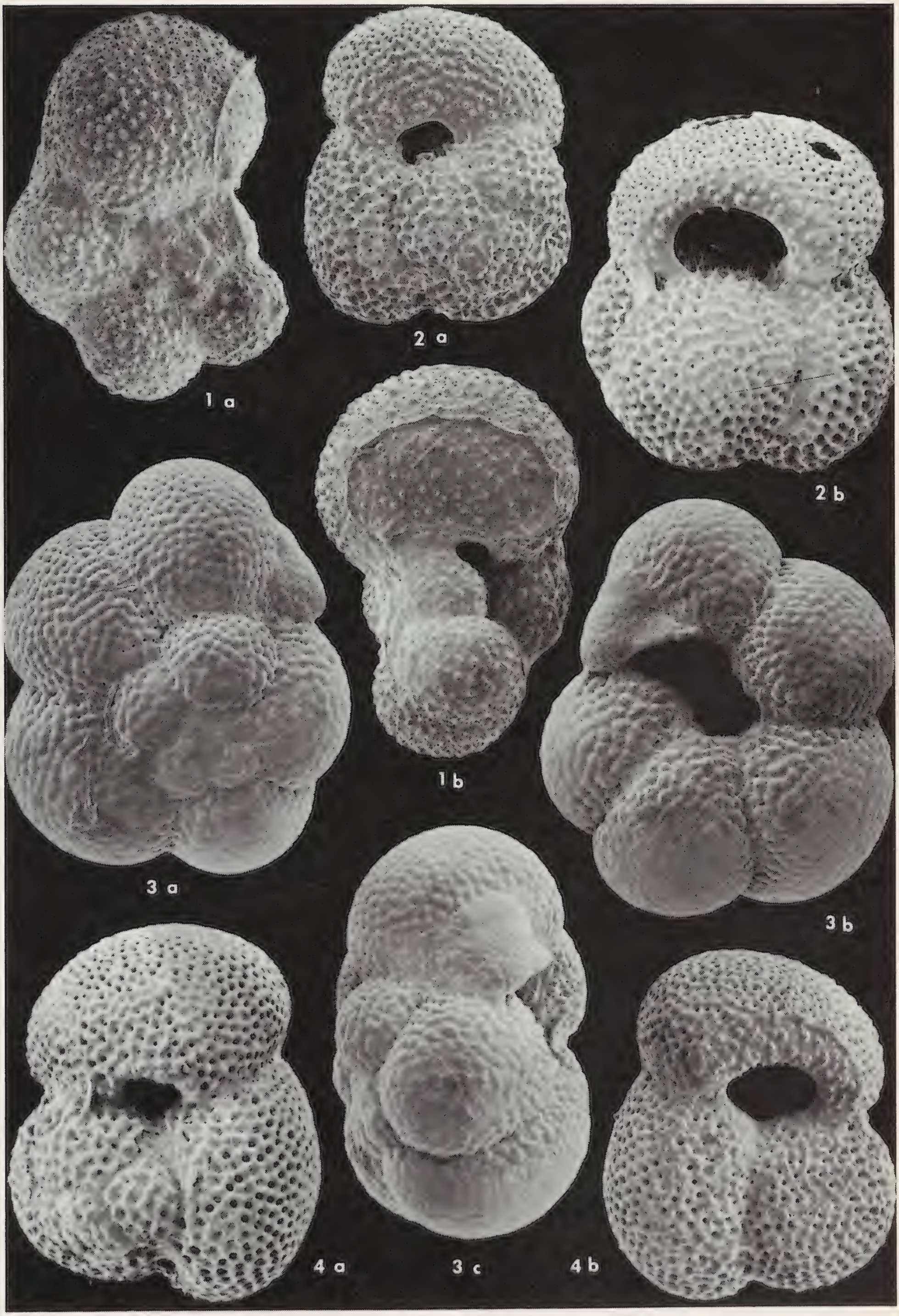


Plate 26

latter consists of a penultimate whorl of three chambers, with the final chamber of the initial whorl to a greater or lesser extent forming part of it; in the following discussion this is termed a whorl of 3 1/2 chambers. However, this fourth chamber is invariably much smaller than the remainder of the chambers in this whorl and thus differs from the relative size of each chamber in the penultimate whorl of *G. subquadratus*. This appears to be a character useful in distinguishing the two species. The other chamber arrangement in *G. ruber* is one in which there are only three chambers in the penultimate whorl. Therefore in *G. subquadratus* removal of three chambers invariably produces a form with four chambers present. However, in *G. ruber* upward of four chambers (frequently six) can be removed before four chambers are seen in ventral view. Many of the specimens in which there is a fourth chamber in the penultimate whorl in dorsal view, when dissected still show the three chambered whorl. However, exceptions occur but this fourth chamber is only just visible." (Cordey, 1957)

Holotype: USNM 548881; from 1.6 miles northeast of the seaward tip of the southwest point of Saipan, Mariana Islands. The dimensions are: length, 0.58 mm; diameter of end chamber, 0.4 mm; diameter of the two preceding chambers, 0.47 mm; diameter of main aperture, ca. 0.11 mm; diameter of accessory aperture of end chamber, ca. 0.07 mm.

*Discussion:* According to Blow, *G. ruber* and *G. subquadratus* do not overlap, and neither species occurs in Zone N. 14 or N. 15. This relationship holds true for the Gulf Coast sequence, since the *Yoldia* Zone of the Choctawhatchee Formation at Cosson's Farm (Yellow River Formation) does not yield either form, although it is one of the more fossiliferous Florida localities from the standpoint of planktonic microfossils. The range of *G. subquadratus* is from Zone N. 5 to the top of Zone N. 13, while *G. ruber* ranges from Zone N. 16 to Zone N. 23, according to Blow.

## Genus GLOBIGERINITA Bronnimann, 1951

### GLOBIGERINITA GLUTINATA (Egger)

Pl. 21, fig. 2; Pl. 33, fig. 3;
Pl. 38, fig. 2

*Globigerina glutinata* EGGER, 1893, Abh. K. Bayer. Akad. Wiss. Munchen, Cl. II, vol. 18, p. 371, pl. 13, figs. 19-21.

*Tinophodella ambitacrena* LOEBLICH and TAPPAN, 1957, Washington Acad. Sci., Jour., vol. 47, no. 4, p. 114, pl., figs. 2, 3.

*Globigerinoides parkerae* BERMUDEZ, 1961, Mem. III Congr. Geol. Venezolano, vol. 3, Bol. Geol. Publ. esp. 3 (1960), p. 1.232, pl. 10, figs. 10, 11.

*Globigerinita glutinata* (Egger). PARKER, 1962, Micropaleontology, vol. 8, no. 2, p. 246, pl. 9, figs. 1-16.

*Globigerinita glutinata* (Egger). PARKER, 1967, Bull. Amer. Paleontology, vol. 52, no. 235, p. 146, pl. 17, figs. 3-5.

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## PLATE 27
## JACKSON BLUFF FORMATION ?
## DARLING SLIDE, LOWER HORIZON

Figures Page

1. *Globigerinoides ruber* (d'Orbigny). . . . . 66
Maximum diameter, 0.49 mm
   a. Spiral view, X 126
   b. Edge view, X 122
   c. Umbilical view, X 126

2. *Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny). . . . . 62
Maximum diameter, 0.60 mm
   a. Spiral view, X 93
   b. Umbilical view, X 91

3. *Globigerinoides obliquus obliquus* Bolli. . . . . 60
Maximum diameter, 0.48 mm
   a. Spiral view, X 126
   b. Edge view, X 119
   c. Umbilical view, X 126

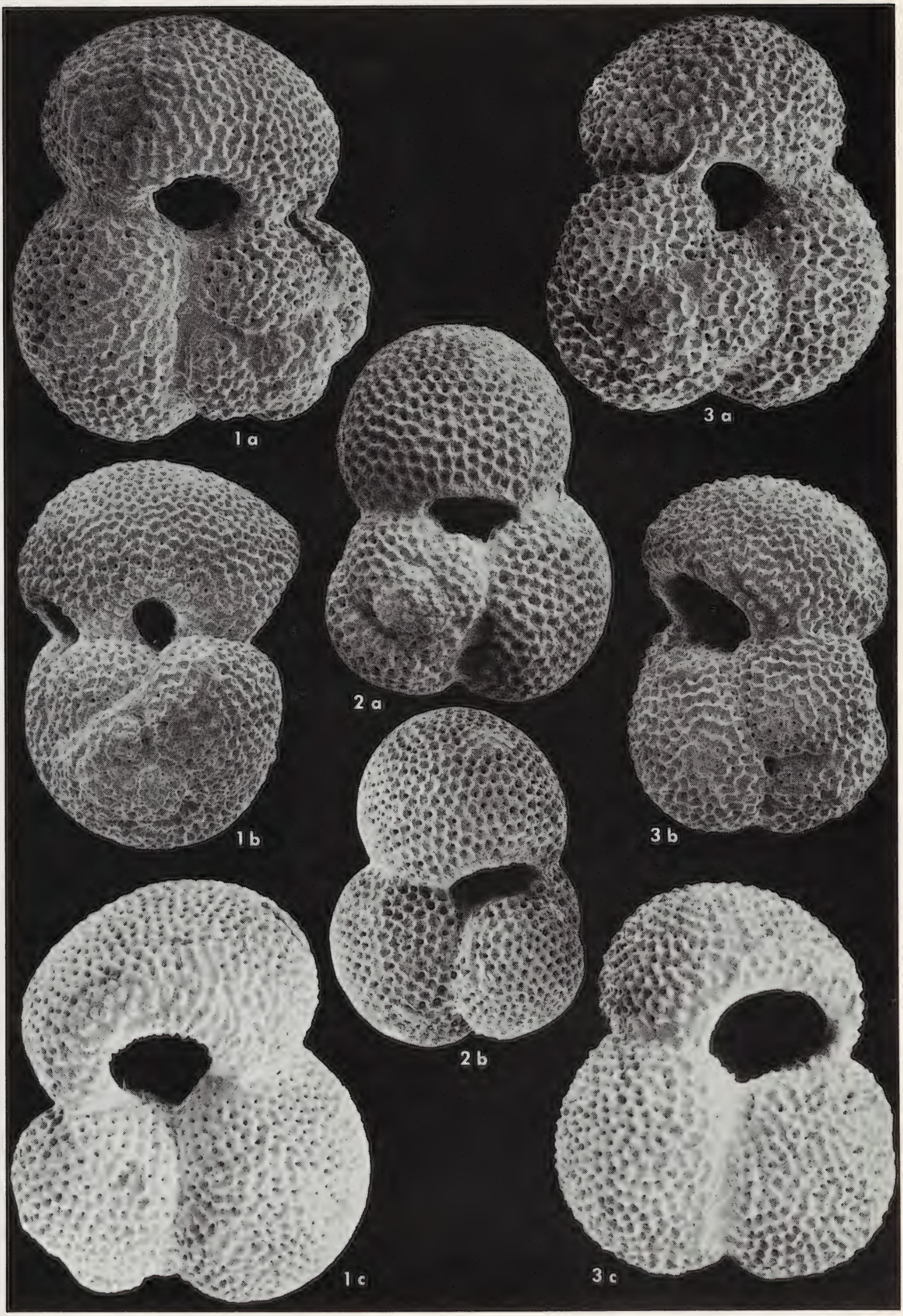


Plate 27

"Das Gehäuse ist der Gestalt nach eine *Globig. triloba* mit etwas höherer Aufrollung der ersten Windung. Die drei Kammern des letzten Umganges liegen, ziemlich wenig in der Grösse verschieden, nebeneinander in der Weise, dass eine einzelne obere, die letzte, und zusammen zwei untere sich gegenüberstehen. Am Saum der letzten Kammer ist auf der Nabelfläche der Oeffnungs-Spalt. Die Nabelmitte ist die einfache Vereinigung der drei Nahte der Kammern. Die Oberfläche der Schale ist ein matt glänzendes Gefüge einer Cementmasse ohne Färbung. Die Scheibenlänge des Gehäuses ist 0.22 mm.

"Die Form des Umrisses gemahnt zum Theil an *Trochammina pauciloculata* aber die Uebereinstimmung mit *Globigerina* ist doch grösser. Von *Globiger. triloba* abzutrennen drängt der Umstrand, dass an manchen Fund-Stellen diese Filzform mehrfach sich findet, dass der Umriss dieser *Gl. glutinans* mehr rundlich bleibt, auch wenn die Schalen werhältnissmassig grösser werden, während bei *Gl. triloba* die letzte Kammer sich etwas mehr aufrichtet. Wo die Schale stachelig aufritt, ist der Unterschied von *Gl. triloba* nicht festzuhalten. Aber gerade bei grösseren Exemplaren tritt in der Regel der Unterschied beider Arten besonders hervor in der Weise, dass *Glob. glutinata* die Schale zart und mattglatt erhält, während die Poren bei *Gl. triloba* sehr gross und mit derbem Zwischenmaschennetz ausgestattet erscheinen." (Egger, 1893)

Holotype: type locality and depository for the type specimen were not given.

*Discussion:* The range of this form, which Blow (1969, p. 327) recognizes as *Globigerinita ambitacrena* (Loeblich and Tappan) is from Zone N. 5 to Zone N. 23.

## GLOBIGERINITA UVULA (Ehrenberg)

Pl. 1, fig. 2; Pl. 15, fig. 2;
Pl. 29, fig. 3; Pl. 52, fig. 1

*Pylodexia uvula* EHRENBERG, 1861, K. Preuss, Akad. Wiss. Berlin, Monatsber., pp. 276-277, 308.

*Pylodexia uvula* Eherenberg. EHRENBERG, 1873, K. Akad. Wiss. Berlin, Abh., Jahrg. 1872, pl. 2, figs. 24, 25.

*Globigerina* sp. BRADY, 1884, Rept. Voy. *Challenger,* Zoology, vol. 9, p. 603, pl. 82, figs. 8, 9.

*Globigerina bradyi* WIESNER *in* DRYGALSKI, 1931, Deutsche Südpolar Exped. 1901-1903, vol. 20 (Zoology, vol. 12), p. 133.

*Globigerinoides minuta* NATLAND, 1933, Univ. Calif., Scripps Inst. Oceanography, Bull., Tech. Ser., vol. 3, no. 10, line 34 of table (nomen nudum).

*Globigerinoides minuta* NATLAND, 1938, Univ. Calif., Scripps Inst. Oceanography, Bull., Tech. Ser., vol. 4, no. 5, p. 150, pl. 7, figs. 2, 3.

*Globigerina bradyi* Wiesner. BANNER and BLOW, 1960, Cushman Found. Foram. Res., Contr., vol. 11, p. 5, pl. 3, figs. 1 (lectotype), 2.

*Globigerinita uvula* (Ehrenberg). PARKER, 1962, Micropaleontology, vol. 8, no. 2, p. 252, pl. 8, figs. 14-26.

*Globigerinita uvula* (Ehrenberg). PARKER, 1967, Bull. Amer. Paleontology, vol. 52, no. 235, p. 146, pl. 17, figs. 8, 9.

"Aristerospira laeviuscula elongata, cellulis majoribus, parietibus tenuibus integris, apertura ampla centro adversa. Cellulis 12 1/18'" longa, prima 1/192'", ambitu primo 1/60'" fere. Visceribus fuscis tota repleta." (Ehrenberg, 1861)

Holotype: depository for type specimen not given; type locality given as "E fundo groenlandico

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## PLATE 28

JACKSON BLUFF FORMATION ?
DARLING SLIDE, LOWER HORIZON

Figures Page

1. *Globorotaloides hexagona hexagona* (Natland). . . . . 124
Maximum diameter, 0.31 mm
   a. Spiral view, X 185
   b. Edge view, X 185
   c. Umbilical view, X 185
   d. View of wall on umbilical side, X 1400

2. *Globorotalia (Turborotalia) acostaensis humerosa* Takayanagi and Saito. . . . . 108
Maximum diameter, 0.53 mm
   a. Spiral view, X 112
   b. Edge view, X 112
   c. Umbilical view, X 112

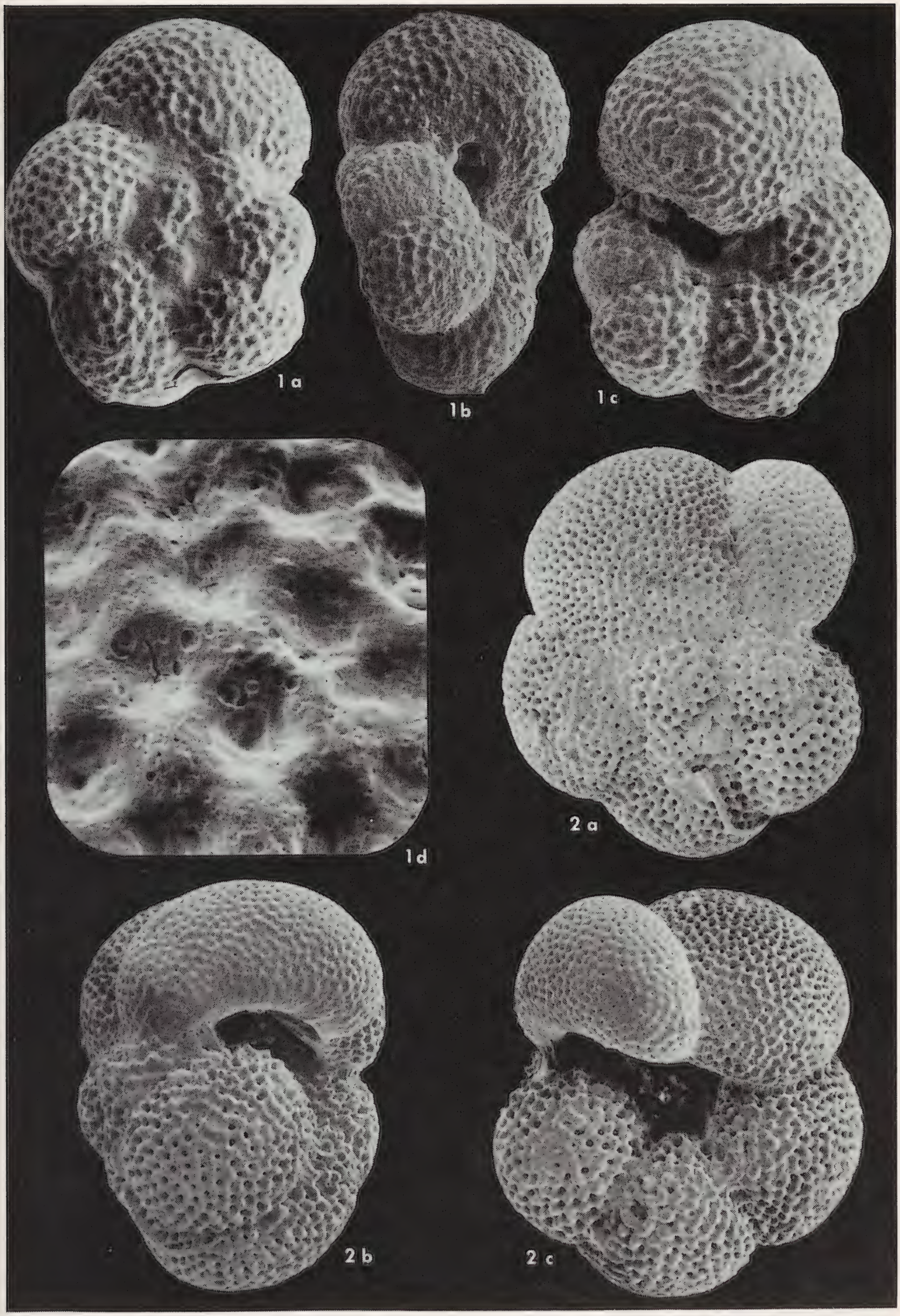


Plate 28

6000' alto, lat., 62° 40' N., long., 29° W., Tiefgrund der Davis-Strasse."

*Discussion:* Blow (1969, p. 316) gives a range from Zone N. 4 to Zone N. 23 for *Globigerina bradyi* Wiesner.

The aperture of Chipola specimens is a high arch similar to that in the lectotype of Banner and Blow. These authors noted variability in the aperture, and for this reason it is concluded that the figured specimens of Parker (1967) are conspecific, although her forms from the Pacific have a low, lipped aperture.

## Genus ORBULINA d'Orbigny, 1839

### ORBULINA SUTURALIS Bronnimann

*Orbulina suturalis* BRONNIMANN, 1951 (part), Cushman Found. Foram. Res., Contr., Vol. 2, pt. 4, p. 135, text-fig. 2, nos. 1-2, 5-8, 10; text-fig. 3, nos. 3-8, 11, 13-16, 18, 20-22; text-fig. 4, nos. 2-4, 7-12, 15-16, 19-22.

*Orbulina suturalis* Bronnimann. BLOW, 1956, Micropaleontology, vol. 2, no. 1, p. 66, text-fig. 2, nos. 5-7.

*Orbulina suturalis* Bronnimann. BOLLI, 1957, U.S. Natl. Mus., Bull. 215, p. 115, pl. 27, fig. 4.

"End chamber globular, not entirely enveloping the preceding *Globigerina* chambers. Tests showing all transitional stages from a partly enveloped *Globigerina* to an almost completely enveloped one. In the final stage, the *Globigerina* chambers visible only as a small rounded area, projecting slightly above the general surface. Tests small. No definite aperture present, but subcircular to irregularly shaped openings occur along sutures, separating the *Globigerina* chambers from the globular end chamber and occasionally outside the sutural grooves as well. Wall cancellate, with regularly arrranged minute perforations, thin or fairly thick, composed of one or more layers. Diameter of holotype, 0.312 mm." (Bronnimann, 1951)

Holotype: USNM 64181; Naparima area, Trinidad, B. W. I., "upper part of the lower Miocene."

*Discussion:* The form ranges from the base of Zone N. 9 to Zone N. 23, according to Blow (1969, p. 334).

### ORBULINA UNIVERSA d'Orbigny

Pl. 10, fig. 2

*Orbulina universa* D'ORBIGNY *in* DE LA SAGRA, 1839, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 2, pl. 1, fig. 1.

*Orbulina universa* d'Orbigny. BLOW, 1956, Micropaleontology, vol. 2, no. 1, p. 55, text-fig. 2, nos. 8, 9.

"*Orbulina.* Testa bullata, sphaerica, tenui, irregulariter, minutissime perforata; apertura circulari.

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## PLATE 29
## JACKSON BLUFF FORMATION ?
## DARLING SLIDE, UPPER HORIZON

Figures Page

1. *Globigerina druryi decoraperta* Takayanagi and Saito. . . . . .50
   Maximum diameter, 0.24 mm
   a. Spiral view, X 204
   b. Edge view, X 204
   c. Umbilical view, X 204

2. *Globigerina* sp. . . . . .17
   Maximum diameter, 0.36 mm
   a. Spiral view, X 142
   b. Edge view, X 142
   c. Umbilical view, X 142

3. *Globigerinita uvula* (Ehrenberg). . . . . .72
   Maximum diameter, 0.27 mm
   a. Spiral view, X 206
   b. Edge view, X 206
   c. Umbilical view, X 206

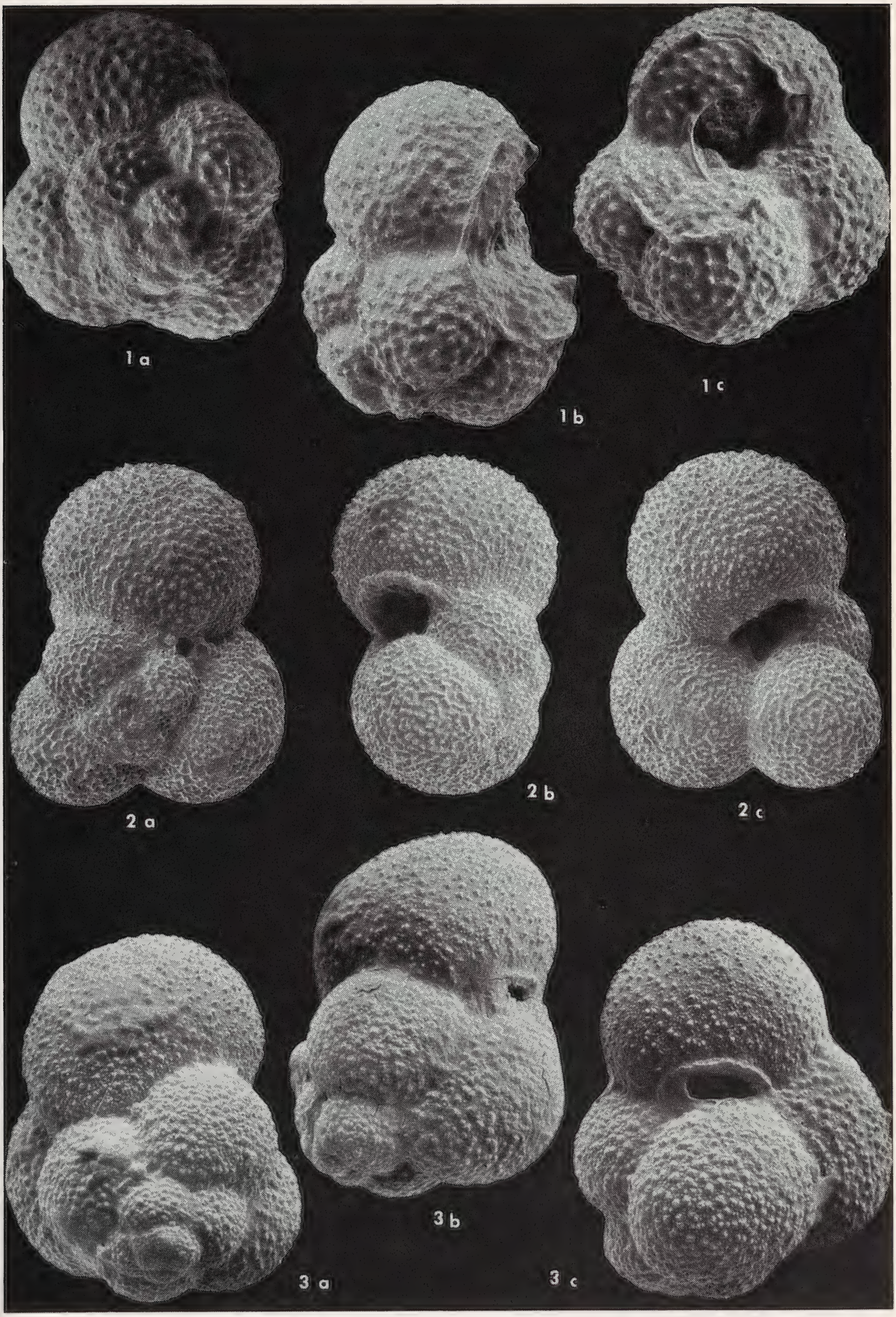


Plate 29

"Dimensions: 1/2 millim. Coquille globuleuse, sphérique, réguliere, très mince, assez rugueuse, couverte partout de très petits trous. Ouverture arrondie, Couleur blanc jaunâtre." (d'Orbigny, 1839)

Holotype: depository not given. D'Orbigny's specimens, however, were from Recent sediments, localities enumerated as follows: "Les bords de l'Adriatique près de Rimini (Emilia), Italy; la côte de l'Algérie; Téneriffe (Canaries); Cuba, la Jamaïque Saint-Thomas, la Guadeloupe, et la Martinique (Antilles); les mers de l'Inde."

*Discussion:* The diagnosis of Blow (1956) is accepted, although there have been suggestions and some evidence (which the writer regards as inconclusive) that this form may embrace several species or even genera (Rhumbler, 1911; Parker, 1962; Bandy *et al.*, 1965). This species, in which the last chamber completely envelops the earlier, globigerine part of the test, ranges from within the early to the middle part of Zone N. 9 to Zone N. 23, according to Blow (1969, p. 334). *Orbulina universa* is abundant at the type locality of the Yellow River Formation (Cosson's Farm) along with *O. suturalis* and *Biorbulina bilobata*. Many of the tests were dissected to reveal the juvenile stage, which, in every case was a globigerine form very similar in test morphology to *Globigerina bulloides bulloides* d'Orbigny.

## Genus BIORBULINA Blow, 1956

### BIORBULINA BILOBATA (d'Orbigny)

*Globigerina bilobata* D'ORBIGNY, 1846, Foraminifères fossiles du bassin tertiaire de Vienne, p. 164, pl. 9, figs. 11-14.

*Globigerina bilobata* d'Orbigny. BANNER and BLOW, 1960, Cushman Found. Foram. Res., Contr., vol. 11, pp. 2-3, pl. 3, fig. 9 (lectotype). (lectotype).

*Biorbulina bilobata* (d'Orbigny). BLOW, 1969, Proc. First International Conference on Planktonic Microfossils, vol. 1, p. 334, pl. 23, figs. 5, 6.

"The large test is bilobate, consisting exteriorly of two sub-equal and partially embracing spheres, but without any external trace of any chambers earlier than the penultimate. The suture between the penultimate and last chamber is distinct and depressed, and no apertural pores were observed in the suture. No external primary aperture exists, but a very few apertural pores are present, apparently randomly distributed over both the ultimate and penultimate chambers. The wall is calcareous, radial in structure, and is uniformly and coarsely perforate, but otherwise smooth, with little trace of the original hispidity. The surfaces of the ultimate and penultimate chambers are virtually identical, and the wall thicknesses appear to be the same. Maximum dimension of lectotype: 0.76 mm." (Banner and Blow, 1960)

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## PLATE 30
## JACKSON BLUFF FORMATION ?
## DARLING SLIDE, UPPER HORIZON

Figures Page

1. *Globigerina bulloides apertura* Cushman. . . . . 46
Maximum diameter, 0.45 mm
   a. Spiral view, X 122
   b. Umbilical view, X 126

2. *Globigerina bulloides bulloides* d'Orbigny. . . . . 48
Maximum diameter, 0.45 mm
   a. Edge view, X 134
   b. Spiral view, X 134
   c. Umbilical view, X 134

3. *Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny). . . . . 62
Maximum diameter, 0.52 mm
   a. Spiral view, X 107
   b. Edge view, X 106
   c. Umbilical view, X 106

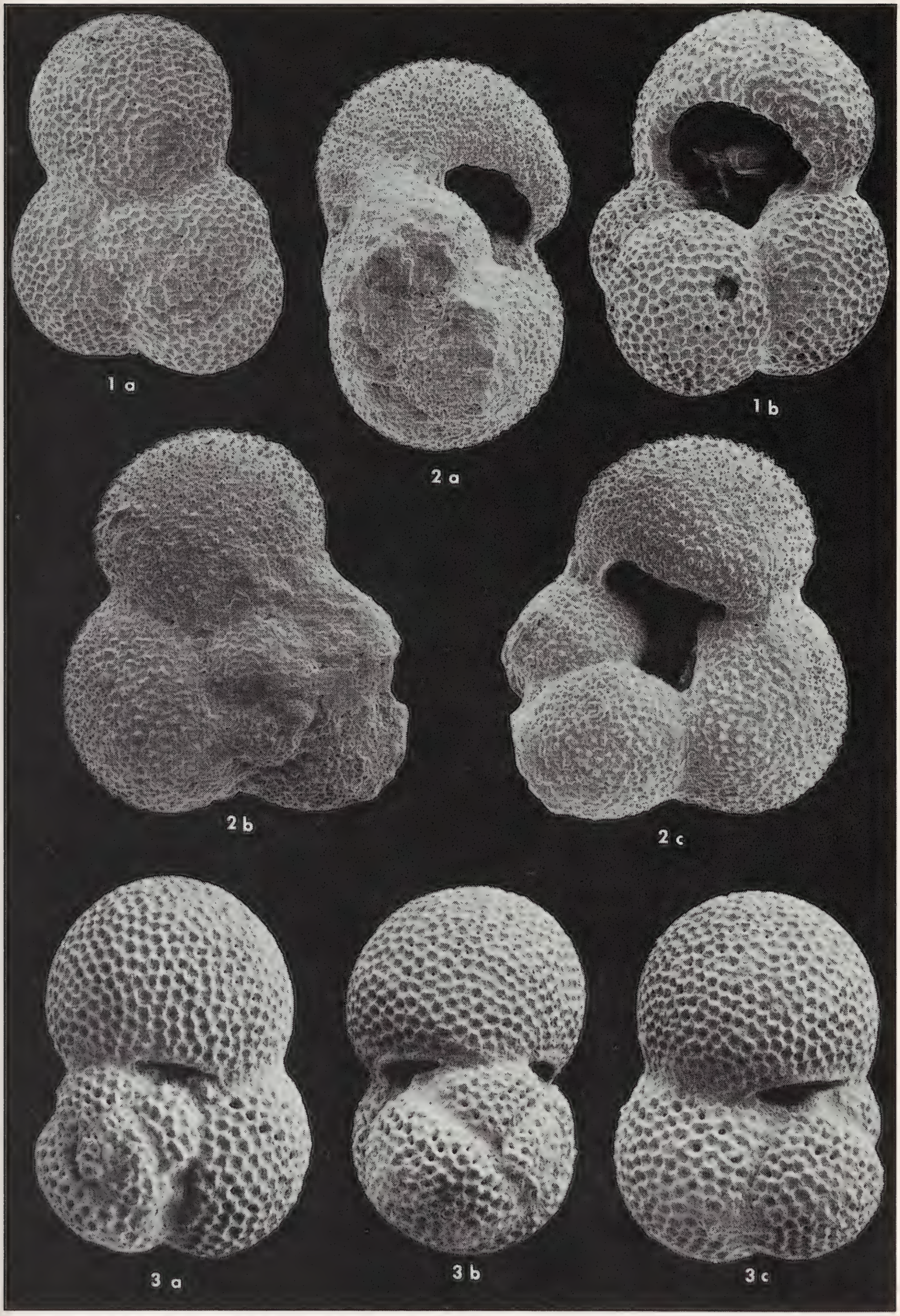


Plate 30

Lectotype: d'Orbigny Collection, Museum National de l'Histoire Naturelle, Paris; Tortonian (?) marly clays, near Nussdorf, Austria.

*Discussion:* Blow has presented a strong argument for the non-teratoid development of this form from *Globigerinoides sicanus* via *Praeorbulina transitoria,* and he believes that it ranges from near the base of Zone N. 9 to Zone N. 23.

## Subfamily SPHAEROIDINELLINAE Banner and Blow, 1959

## Genus SPHAEROIDINELLA Cushman, 1927

### SPHAEROIDINELLA DEHISCENS DEHISCENS (Parker and Jones)

Pl. 45, fig. 2; Pl. 59, fig. 3

*Sphaeroidina bulloides* d'Orbigny var. *dehiscens* PARKER and JONES, 1865, Roy. Soc. London, Philos. Trans., vol. 155, p. 369, pl. 19, fig. 5.

*Sphaeroidina bulloides* d'Orbigny var. *dehiscens* Parker and Jones. BANNER and BLOW, 1960, Cushman Found. Foram. Res., Contr., vol. 11, p. 35, pl. 7, fig. 3 (lectotype).

*Sphaeroidinella dehiscens dehiscens* (Parker and Jones). BLOW, 1969, Proc. First International Conference on Planktonic Microfossils, vol. 1, p. 336, pl. 29, fig. 9.

"The large globose test shows only three chambers externally. The chambers are subspherical, much inflated, partially embracing, rapidly enlarging and appear to be trochospirally coiled. The test is involute both dorsally and ventrally. The sutures are broadly depressed and the periphery of the test is broadly lobulate. The apertures are sutural and multiple. The primary aperture appears to be interiomarginal, umbilical and ventral in position, but it, like the umbilicus, is infilled by extraneous material. The dorsal supplementary aperture is sutural in position but it is also infilled with extraneous material and consequently its true extent and nature cannot be ascertained in the lectotype. The apertures are furnished with thick flange-like lips of clear imperforate shell material; these flanges extend around the umbilical margins of the chambers and on both sides of the supplementary aperture. The sutures appear to be deeply incised in the vicinity of the apertures and the flanges border these incisions throughout their length and in part bridge them. The wall of the test is calcareous, apparently radial in structure and it is uniformly and coarsely perforate except for the flange-like areas. The surface of the

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## PLATE 31
## JACKSON BLUFF FORMATION ?
## DARLING SLIDE, LOWER HORIZON

Figures Page

1. *Globigerina bulloides apertura* Cushman. . . . . 46
Maximum diameter 0.40 mm
a. Spiral view, X 136
b. Edge view, X 136
c. Umbilical view, X 136

2. *Globigerina bulloides bulloides* d'Orbigny. . . . . 48
Maximum diameter, 0.37 mm
a. Umbilical view, X 136
b. Spiral view, X 136

3. *Globigerina druryi decoraperta* Takayanagi and Saito. . . . . 50
Maximum diameter, 0.23 mm
a. Umbilical view, X 189
b. Spiral view, X 189

4. *Hastigerina (Hastigerina) siphonifera siphonifera* (d'Orbigny). . . . . 124
Maximum diameter, 0.38 mm
a. Edge view, X 133
b. Umbilical view, X 133

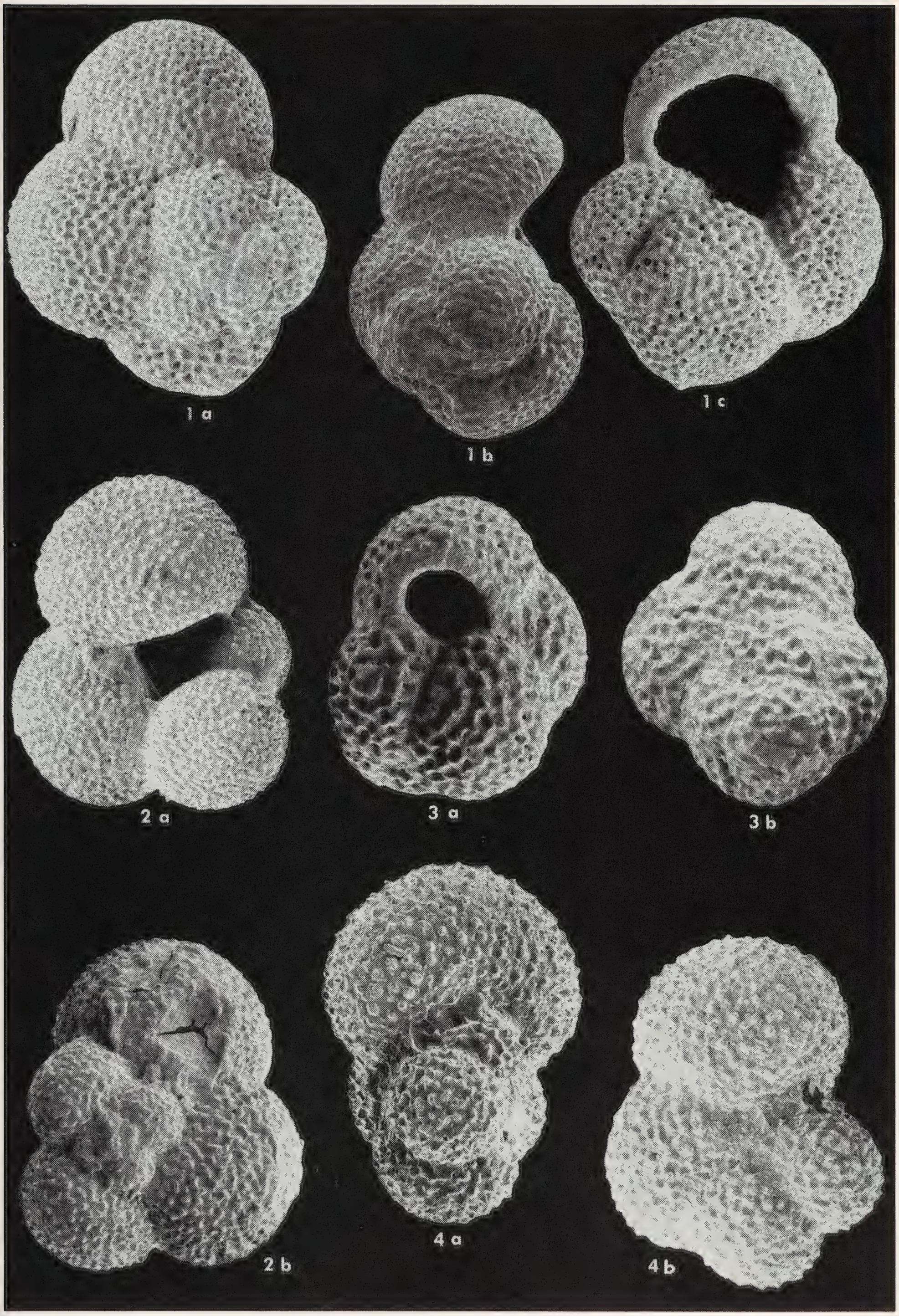


Plate 31

test is smooth and highly polished especially in the vicinity of the apertures where the material of the flanges appears to spread thickly over the chamber surfaces. Maximum diameter of lectotype: 0.88 mm." (Banner and Blow, 1960)

Lectotype: British Museum (Natural History) ZF. 3580; Atlantic Ocean, 2° 20' N., 28° 44' W., at 1080 fathoms.

*Discussion:* The range of this form is from the base of Zone N. 19, to Zone N. 23 (Blow, 1969).

## SPHAEROIDINELLA DEHISCENS DEHISCENS forma IMMATURA (Cushman)

*Sphaeroidina dehiscens* Parker and Jones var. *immatura* CUSHMAN, 1919, Carnegie Inst. Washington, Publ. No. 291, p. 40, pl. 14, fig. 2.

*Sphaeroidinella dehiscens dehiscens* forma *immatura* (Cushman). BLOW, 1969, Proc. First International Conference on Planktonic Microfossils, vol. 1, p. 336, pl. 29, figs. 6-8.

"Test exteriorly composed almost entirely of two visible chambers, with a small portion of a third sometimes slightly showing; chambers spherical, walls coarsely perforate, suture between the chambers very slightly fissure-like on opposite sides, otherwise closed and simply depressed. Diameter, 0.4 to 0.5 mm.

"All of the specimens from the Bowden marl seem to belong to this species, but they are very constant in having the characters only slightly developed, the usual separation of the chambers being barely indicated and the division, instead of being a deep-cut fissure, is merely a simple cut in the central part of the sutural region at either side. The specimens also are very small but are uniform in size and in general characters." (Cushman, 1919)

Holotype: depository not designated for the type specimen.

*Discussion:* Cushman (1919, p. 28) states that all of his specimens are from the Bowden Marl at Bowden, Jamaica. Blow (1969, p. 336 and pl. 29) refers to Cushman's locality as the "Buff Bay Beds" of Cushman and Jarvis (1930), not Buff Bay Formation of Hill (1899). Blow refers specimens from this locality to both *Sphaeroidinella dehiscens* forma *immatura* and to *Sphaeroidinellopsis subdehiscens paenedehiscens* Blow. He considers adult *S. dehiscens dehiscens* forma *immatura* to be phylogenetically primitive forms of *S. dehiscens dehiscens* and to be confined to Zone N. 19.

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## PLATE 32
## JACKSON BLUFF FORMATION ?
## DARLING SLIDE, UPPER HORIZON

Figures Page

1. *Globorotalia (Globorotalia) margaritae* Bolli and Bermúdez. . . . . 102
   Maximum diameter, 0.49 mm
   a. Spiral view, X 104
   b. Edge view, X 104
   c. Umbilical view, X 104

2. *Globorotalia (Globorotalia) cultrata* subsp. . . . . 17
   Maximum diameter, 0.42 mm
   a. Spiral view, X 134
   b. Edge view, X 133
   c. Umbilical view, X 133

3. *Globorotalia (Turborotalia) praeoscitans* Akers, new species . . . . . 116
   USNM 180584, paratype. Maximum diameter, 0.30 mm
   a. Umbilical view, X 200
   b. Edge view, X 200
   c. Spiral view, X 200

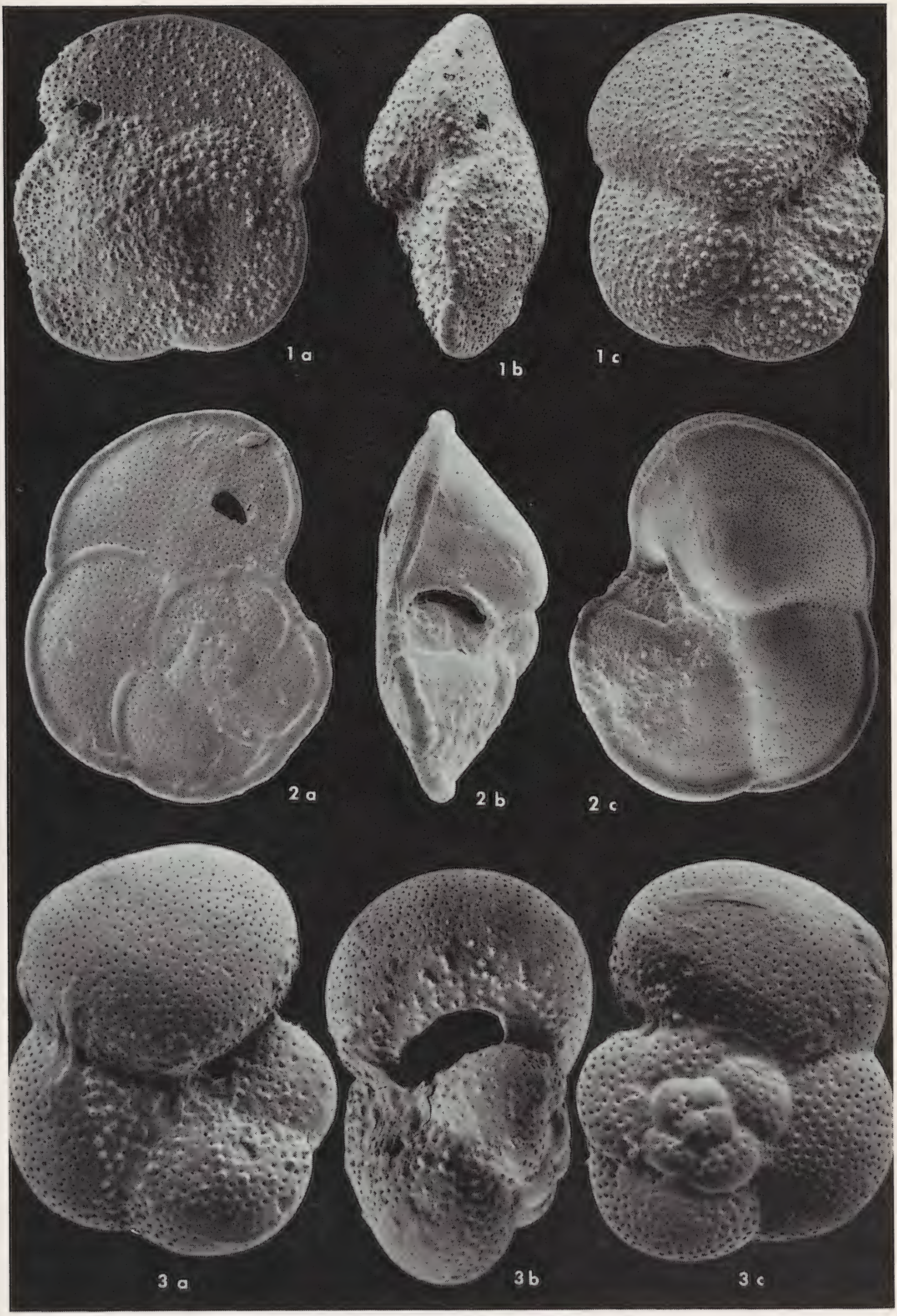


Plate 32

## Genus SPHAEROIDINELLOPSIS Banner and Blow, 1959

### SPHAEROIDINELLOPSIS SEMINULINA KOCHI (Caudri)

Pl. 12, fig. 3

*Globigerina* sp. KOCH, 1923, Bericht. Schweiz. Pal. Ges., vol. 18, p. 355, text-figs. 82-b.

*Globigerina kochi* CAUDRI, 1934, Tertiary Deposits of Soemba, p. 144.

*Sphaeroidinella seminulina kochi* (Caudri). BLOW, 1959, Bull. Amer. Paleontology, vol. 39, no. 178, p. 198, pl. 12, figs. 78-79.

*Sphaeroidinellopsis seminulina kochi* (Caudri). BLOW, 1969, Proc. First International Conference on Planktonic Microfossils, vol. 1, p. 337, pl. 30, fig. 8.

"It is a small, flat *Globigerina,* on the upper side of which a close somewhat excentric spiral is seen of small chambers, not easily to be distinguished one from another, while on the other side only 4 chambers are visible. These 4 chambers gradually increase in size from the earliest to the latest and the last chamber is slightly elongated horizontally which gives the test something the appearance of a strongly compressed *G. sacculifera.* There are, however, no supplementary apertures on the sutures. The four latest formed chambers lie round an undeep umbilicus; no aperture was observed. The fossils were not good enough to supply further details to Koch's original description." (Caudri, 1934)

Holotype: Naturhistorisches Museum, Basel, Switzerland; Tertiary of Kabu, Residentschaft Surabaja, Java.

*Discussion:* This form ranges from within the later part of Zone N. 10 to within Zone N. 19, according to Blow (1969, p. 337), whose observations are worth repeating here: "It may seem that the forms distinguished here as *S. seminulina kochi* are only ecological variants of *Sphaeroidinellopsis seminulina seminulina.* However, the multi-chambered forms included in *"kochi"* do not seem to occur throughout the whole of the stratigraphic record of *Sphaeroidinellopsis seminulina seminulina* and only develop much later than the first interval at the end of the stratigraphic range of *S. seminulina* (s.s.). The differences in stratigraphic ranges of the two morphotypes are consistently expressed in both deep-sea core material and in land-based stratigraphical sequences regardless of the depositional environments. Consequently, the writer continues to recognize *"kochi"* as being subspecifically distinct from "*seminulina* (sensu stricto)", at least, for biostratigraphical purposes."

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## PLATE 33
## JACKSON BLUFF FORMATION ?
## DARLING SLIDE, LOWER HORIZON

Figures

Page

1. *Globorotalia (Globorotalia) margaritae* Bolli and Bermúdez. . . . . 102
Maximum diameter, 0.37 mm
   a. Spiral view, X 132
   b. Edge view, X 132
   c. Umbilical view, X 132

2. *Globorotalia (Globorotalia) cultrata limbata* (Fornasini). . . . . 98
Maximum diameter, 0.40 mm
   a. Spiral view, X 136
   b. Edge view, X 133
   c. Umbilical view, X 134

3. *Globigerinita glutinata* (Egger). . . . . 70
Maximum diameter, 0.23 mm
   a. Umbilical view, X 265
   b. Umbilical view (with more of last chamber in view), X 227

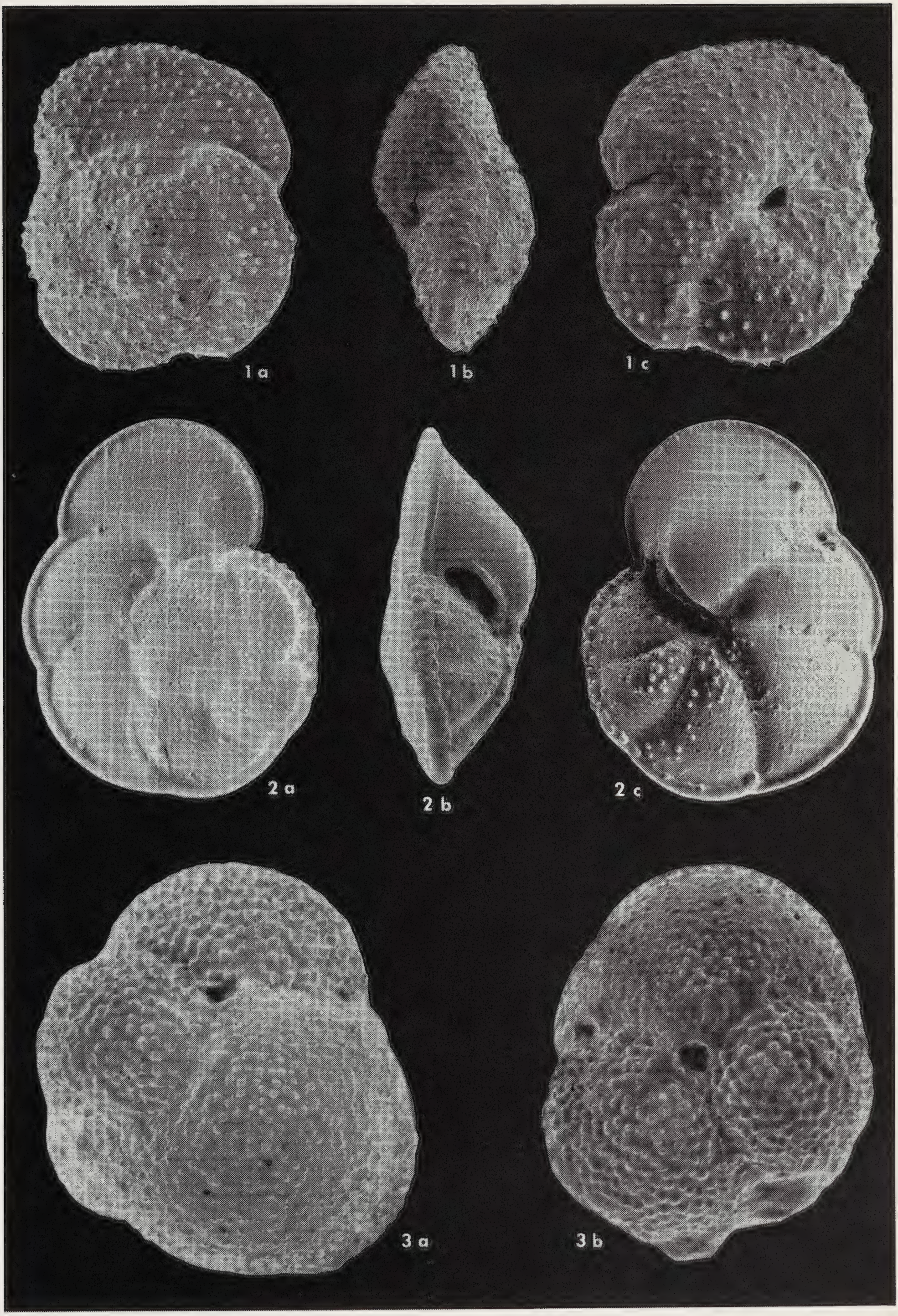


Plate 33

## SPHAEROIDINELLOPSIS SEMINULINA SEMINULINA (Schwager)

Pl. 14, fig. 2

*Globigerina seminulina* SCHWAGER, 1866, *Novara* Exped. 1857-1859, Geol. Theil, vol. 2, pt. 2, p. 256, pl. 7, fig. 112.

*Sphaeroidinella seminulina seminulina* (Schwager). BLOW, 1959, Bull. Amer. Paleontology, vol. 39, no. 178, pp. 197-198, pl. 12, figs. 74-77a-c.

*Globigerina seminulina* Schwager. BANNER and BLOW, 1960, Cushman Found. Foram. Res., Contr., vol. 11, p. 24, pl. 7, figs. 7a-b, (neotype).

*Sphaeroidinellopsis seminulina seminulina* (Schwager). BLOW, 1969, Proc. First International Conference on Planktonic Microfossils, vol. 1, pp. 337-338, pl. 30, fig. 7

"The fairly large test consists of about two whorls of rapidly enlarging, inflated chambers arranged in a low trochospire, with four chambers present in the last whorl. The chambers are initially obscure but probably embracing; they become increasingly well separated, slightly radially elongate and ovoid during the last whorl. The equatorial profile is sub-oval, somewhat elongate in the direction of the last chamber; the equatorial periphery is strongly lobulate. The axial profile is a compressed oval, and the dorsal surface is only very slightly convex. The axial periphery is evenly rounded, tending to become subacute over the last chamber. The dorsal sutures are initially obscure. In the last whorl, the intercameral sutures are slightly but broadly depressed on the ventral and dorsal surfaces and are much more deeply depressed over the periphery. The dorsal intercameral sutures are slightly curved to nearly radial, whilst the ventral intercameral sutures are virtually radial. The umbilicus is broad and probably very deep (infilled in the neotype) and is bordered by broad, clear, hyaline, thickened, crenulate and corrugated flanges, which are the strongly developed lips of the relict parts of the primary apertures of the chambers in the last whorl. The primary aperture is believed to be a low interiomarginal, intraumbilical arch, but it is obscured in the neotype. There are no supplementary apertures present, either dorsally or ventrally. The wall is very thick and coarsely perforate. The surface of the test is covered by a layer of clear shell material which is thickest near the umbilicus; this cortex partially or wholly covers the coarse but sparsely distributed punctations. Maximum diameter of neotype: 0.56 mm." (Banner and Blow, 1960)

Neotype: British Museum (Natural History) P. 44035; obtained by Schwager from the "Pliocene" (? Sarmatian) of Kar Nikobar, sent by him to H. B. Brady.

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## PLATE 34
## JACKSON BLUFF FORMATION
## ECPHORA FAUNIZONE
## JACKSON BLUFF, BED 9

Figures Page

1. *Globigerina bulloides bulloides* d'Orbigny. . . . . 48
   Maximum diameter, 0.35 mm
   a. Spiral view, X 164
   b. Umbilical view, X 168

2. *Sphaeroidinellopsis subdehiscens subdehiscens* Blow. . . . . 86
   Maximum diameter, 0.33 mm
   a. Spiral view, X 164
   b. Umbilical view, X 168

3. *Globigerina druryi decoraperta* Takayanagi and Saito. . . . . 50
   Maximum diameter, 0.29 mm
   a. Umbilical view, X 168
   b. Spiral view, X 168

4. *Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny). . . . . 62
   Maximum diameter, 0.65 mm
   a. Spiral view, X 84
   b. Umbilical view, X 80

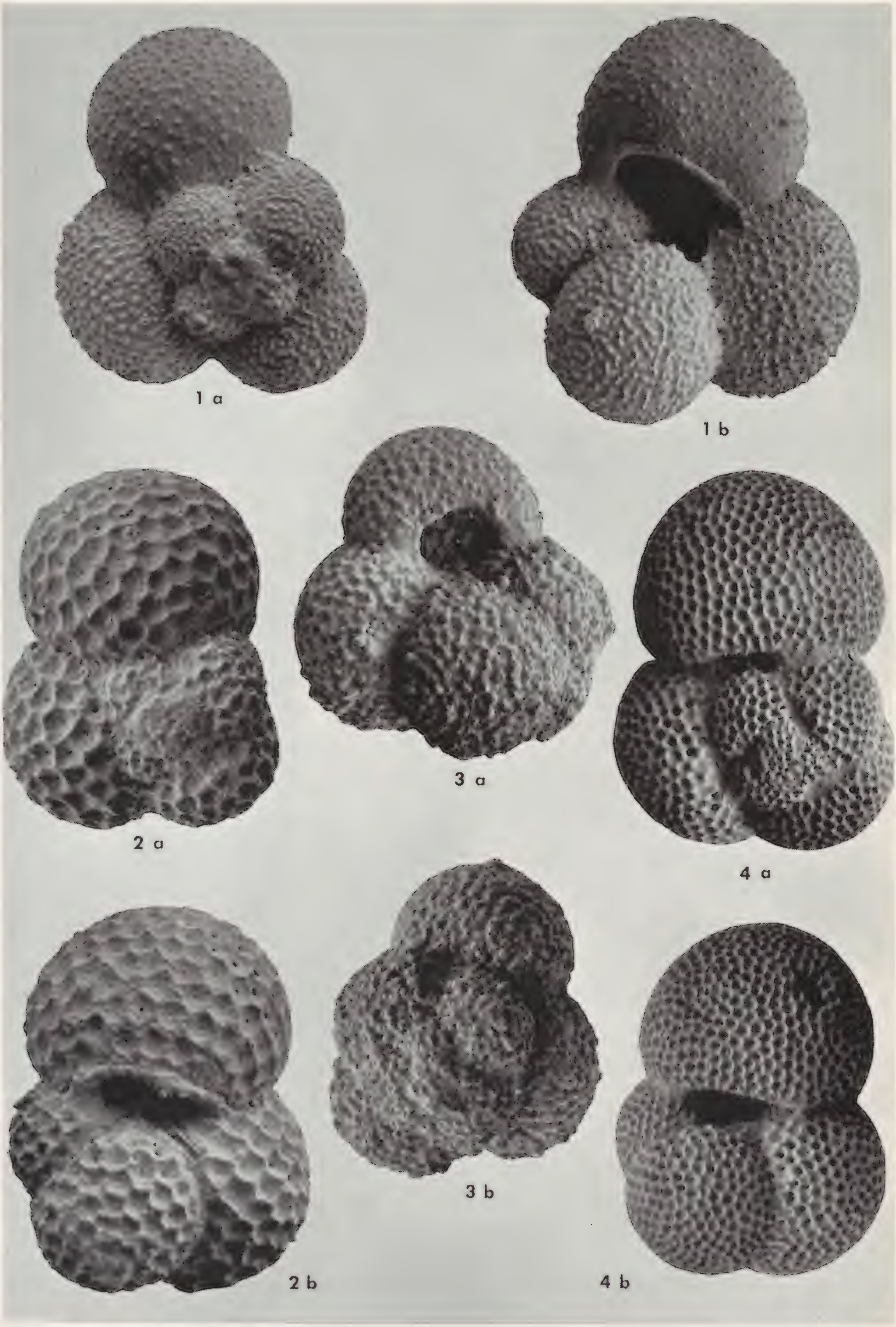


Plate 34

*Discussion:* According to Blow, the range is "from within Zone N. 6 to usually near the Zone N. 20/Zone N. 19 boundary; however, in deep-sea cores, the taxon may range as high as the earlier part of Zone N. 21." The specimen illustrated from the Blount's Creek locality (pl. 14, fig. 2a-b) is decorticated, as is often the case with individuals of this form (Blow, 1969, p. 337; Parker, 1967, p. 161).

## SPHAEROIDINELLOPSIS SUBDEHISCENS SUBDEHISCENS Blow

Pl. 7, fig. 2; Pl. 20, figs. 2-4;
Pl. 34, fig. 2; Pl. 35, figs. 3, 4;
Pl. 39, figs. 1, 3; Pl. 49, fig. 3

*Sphaeroidinella dehiscens subdehiscens* BLOW, 1959, Bull. Amer. Paleontology, vol. 39, no. 178, p. 195, pl. 12, figs. 71, 72.

*Sphaeroidinellopsis subdehiscens subdehiscens* (Blow). BLOW, 1969, Proc. First International Conference on Planktonic Microfossils, vol. 1, p. 338, pl. 30, figs. 1-3; pl. 31, pl. 32.

"Test low trochospiral with three, seldom with three and one half, chambers in the last whorl; chambers, in general, rather embracing, sutures not depressed but usually fairly distinct, especially the suture between the last and earlier chambers; equatorial periphery slightly lobate with the test appearing ovate in equatorial profile; axial periphery rounded; umbilicus small or closed; aperture interiomarginal, umbilical, an elongate slit or low arch, often with thickened and crenulate margins composed essentially of a thickening of the outer cortex; wall calcareous, thick, composed of an outer cortex and a thick inner part which is radial in structure; inner part coarsely perforate, outer part smooth and glassy in reflected light; maximum diameter of holotype, 0.50 mm." (Blow, 1959)

Holotype: USNM 625705; Pozón Formation, eastern Falcón, Venezuela.

*Discussion:* The range, according to Blow (1969, p. 338) is from the base of Zone N. 13 to within Zone N. 19.

## Genus GLOBOQUADRINA Finley, 1947

## GLOBOQUADRINA ALTISPIRA ALTISPIRA (Cushman and Jarvis)

Pl. 44, fig. 1

*Globigerina altispira* CUSHMAN and JARVIS, 1936, Cushman Lab. Foram. Res., Contr., vol. 12, pt. 1, p. 5, pl. 1, figs. 13a-c, 14.

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## PLATE 35
## JACKSON BLUFF FORMATION
## ECPHORA FAUNIZONE
## JACKSON BLUFF, BED 9

Figures — Page

1. *Globigerinoides obliquus obliquus* Bolli. . . . . 60
Maximum diameter, 0.38 mm
a. Umbilical view, X 161
b. Spiral view, X 161

2. *Globigerinoides ruber* (d'Orbigny). . . . . 66
Maximum diameter, 0.52 mm
a. Spiral view, X 104
b. Umbilical view, X 104

3. *Sphaeroidinellopsis subdehiscens subdehiscens* Blow. . . . . 86
Maximum diameter, 0.40 mm
a. Spiral view, X 144
b. Umbilical view, X 144

4. *Sphaeroidinellopsis subdehiscens subdehiscens* Blow. . . . . 86
Maximum diameter, 0.53 mm
a. Umbilical view, X 105
b. Spiral view, X 105

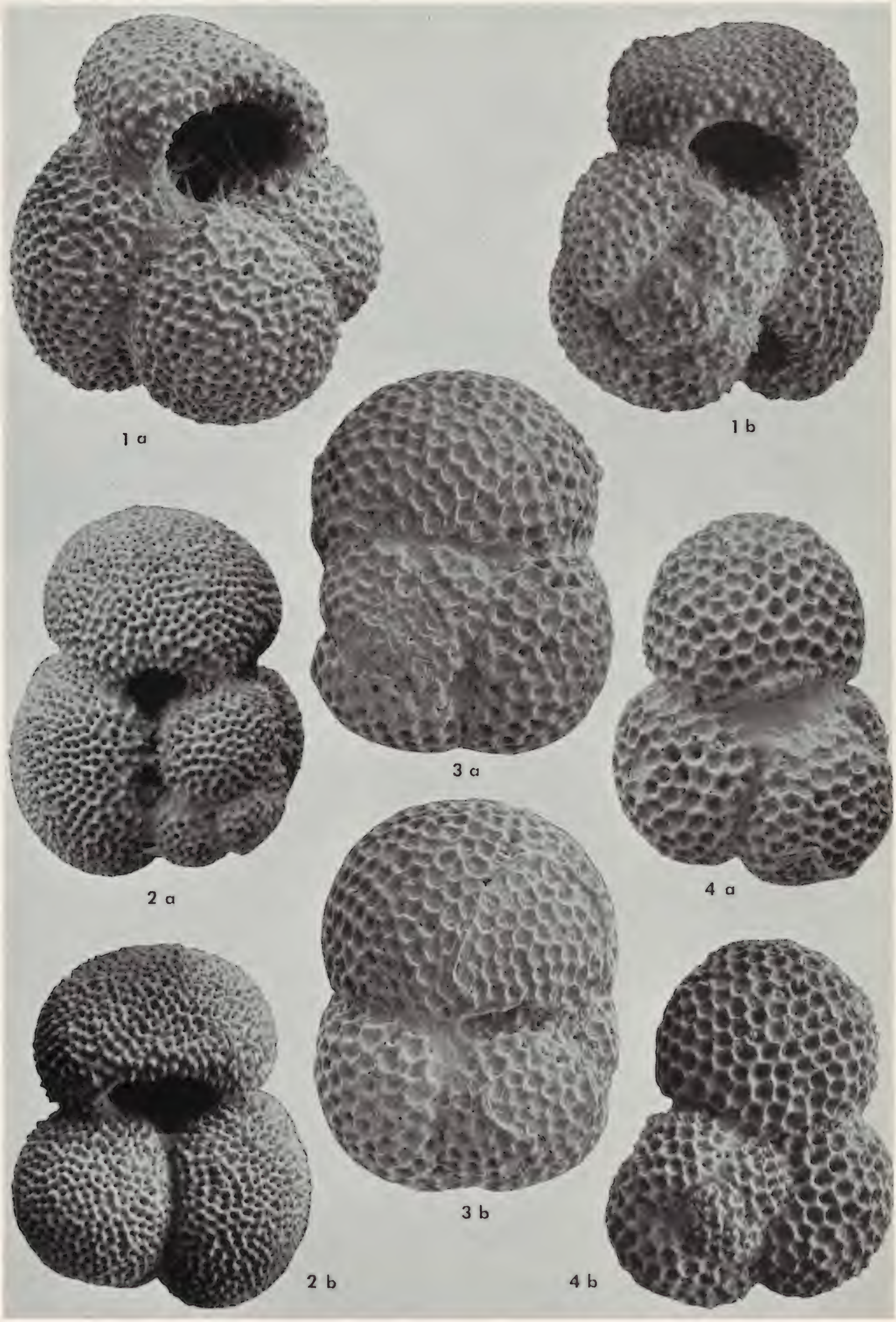


Plate 35

*Globoquadrina altispira altispira* (Cushman and Jarvis). BOLLI, 1957, U. S. Natl. Mus., Bull. 215, p. 111, pl. 24, figs. 7a-8b.

"Test composed of about three whorls in a high spire; chambers much higher than broad in the adult, strongly inflated on the ventral side with a distinct, thin triangular, plate-like structure extending into the umbilicus, about five in the adult whorl; sutures distinct, depressed; wall finely cancellated; aperture on the inner margin opening into the central umbilicus covered by a plate-like tooth. Length, 0.75-0.80 mm; diameter, 0.70 mm." (Cushman and Jarvis, 1936)

Holotype: USNM 22482; from the "Buff Bay beds" of Cushman and Jarvis (1936; not Buff Bay Formation of Hill, 1899), according to Blow (1969, p. 339).

*Discussion:* This subspecies is separated here from *Globoquadrina altispira globosa* Bolli, although, with Parker (1967, p. 165), the writer has failed to find any special stratigraphic significance in the separation. Morphologic variation within the species may have been related directly to ecology rather than genetics. Blow (1969) has found *Globoquadrina altispira altispira* to range from within the earlier part of Zone N. 4 to the earlier part of Zone N. 21.

## GLOBOQUADRINA ALTISPIRA GLOBOSA Bolli

Pl. 8, fig. 2; Pl. 11, fig. 1;
Pl. 15, fig. 1; Pl. 20, fig. 1;
Pl. 25, fig. 1; Pl. 40, fig. 1

*Globoquadrina altispira globosa* BOLLI, 1957, U. S. Natl. Mus., Bull. 215, p. 111, pl. 24, figs. 9, 10.
*Globoquadrina altispira globosa* Bolli. BLOW, 1959, Bull. Amer. Paleontology, vol. 39, no. 178, p. 183, pl. 11, figs. 52a-c.

"Shape of test medium to high trochospiral; equatorial periphery distinctly lobate. Wall calcareous, perforate, surface finely pitted, with short spines on well preserved specimens. Chambers spherical to very slightly compressed laterally; 15-20, arranged in 3-4 whorls; the 5-6 chambers of the last whorl increase moderately in size. Sutures on spiral side radial, depressed; on umbilical side radial, depressed. Umbilicus fairly wide, deep. Aperture high, covered above by an elongate, toothlike flap; interiomarginal, umbilical. Coiling random in the *Catapsydrax dissimilis* zone, later becoming predominantly sinistral (as is also *Globoquadrina altispira altispira* and *Globoquadrina dehiscens;* Bolli, 1951). Largest diameter of holotype, 0.7 mm." (Bolli, 1957)

Holotype: USNM P5626; from the type locality of the *Catapsydrax dissimilis* Zone, Trinidad.

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## PLATE 36
## JACKSON BLUFF FORMATION
## ECPHORA FAUNIZONE
## JACKSON BLUFF, BED 9

Figures — Page

1. *Globorotalia (Globorotalia) cultrata* subsp. . . . . 20
Maximum diameter, 0.58 mm
a. Spiral view, X 87
b. Umbilical view, X 90
c. Edge view, X 87

2. *Globorotalia (Turborotalia) acostaensis humerosa* Takayanagi and Saito. . . . . 108
Maximum diameter, 0.48 mm
a. Spiral view, X 122
b. Edge view, X 126
c. Umbilical view, X 122

3. *Globorotalia (Turborotalia) praeoscitans* Akers, new species . . . . . 116
USNM 180565, paratype. Maximum diameter, 0.31 mm
a. Edge view, X 162
b. Umbilical view, X 164
c. Spiral view, X 162

Plate 36

*Discussion:* The range, according to Blow (1969, p. 399) is from Zone N. 3 to Zone N. 19 or the earliest part of Zone N. 20. Parker (1967, p. 165) sees no stratigraphic basis for separating this form from *G. altispira s. s.*, nor does the writer. However, *G. altispira globosa* is a distinctive morphotype in assemblages investigated for this report with no gradations toward the form with less globular and more elongate chambers.

## GLOBOQUADRINA BAROEMOENENSIS (LeRoy)

Pl. 3, fig. 3; Pl. 5; figs. 2-3

*Globigerina baroemoenensis* LEROY, 1939, Natuurk. Tijdschr. Nedrl.-Indie, Batavia, Java, vol. 99, no. 6, p. 263, pl. 6, figs. 1-2.

*Globoquadrina baroemoenensis* (LeRoy). BLOW, 1969, Proc. First International Conference on Planktonic Microfossils, vol. 1, pp. 340-341, pl. 28, figs. 4, 8.

"Test medium, about as broad as high, ventral umbilical area widely opened, dorsally shows flattened spiral arrangement of chambers which enlarges rapidly, the last three or four constituting the greater part of the test; chambers distinct, inflated, last one somewhat flattened on outer margin toward lower part; sutures distinct, deeply depressed; wall smooth, moderately perforate; aperture a large opening on ventral side, covered with a distinct, narrow, sometimes protruding lip. Diameter, 0.50 mm." (LeRoy, 1939)

Holotype: in the collections of the Javanese Geological Survey (*teste* Dr. H. M. S. Hartono, *fide* Blow, 1969, p. 340); Telisa Formation of Central Sumatra.

*Discussion:* The range is from within the later part of Zone N. 2 to Zone N. 16, according to Blow.

Chipola specimens compare closely with LeRoy's holotype figure, as well as with specimens figured by Blow.

## GLOBOQUADRINA CONGLOMERATA (Schwager)

*Globigerina conglomerata* SCHWAGER, 1866, *Novara* Exped. 1857-1859, Geol. Theil. vol. 2, pt. 2, p. 255, pl. 7, fig. 113.

*Globigerina conglomerata* Schwager. BANNER and BLOW, 1960, Cushman Found. Foram. Res., Contr., vol. 11, p. 7, pl. 2, fig. 3 (neotype).

*Globoquadrina conglomerata* (Schwager). PARKER, 1967, Bull. Amer. Paleontology, vol. 52, no. 235, pp. 165-166, pl. 27, fig. 4.

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## PLATE 37
## JACKSON BLUFF FORMATION
## CANCELLARIA FAUNIZONE
## JACKSON BLUFF, BED 10

Figures Page

1. *Globigerina bulloides apertura* Cushman. . . . . 46
   Maximum diameter, 0.39 mm
   a. Spiral view, X 127
   b. Edge view, X 127
   c. Umbilical view, X 129

2. *Globigerina druryi decoraperta* Takayanagi and Saito. . . . . 50
   Maximum diameter, 0.24 mm
   a. Spiral view, X 204
   b. Edge view, X 204
   c. Umbilical view, X 206

3. *Globigerina bulloides bulloides* d'Orbigny. . . . . 48
   Maximum diameter, 0.34
   a. Spiral view, X 153
   b. Edge view, X 153
   c. Umbilical view, X 154

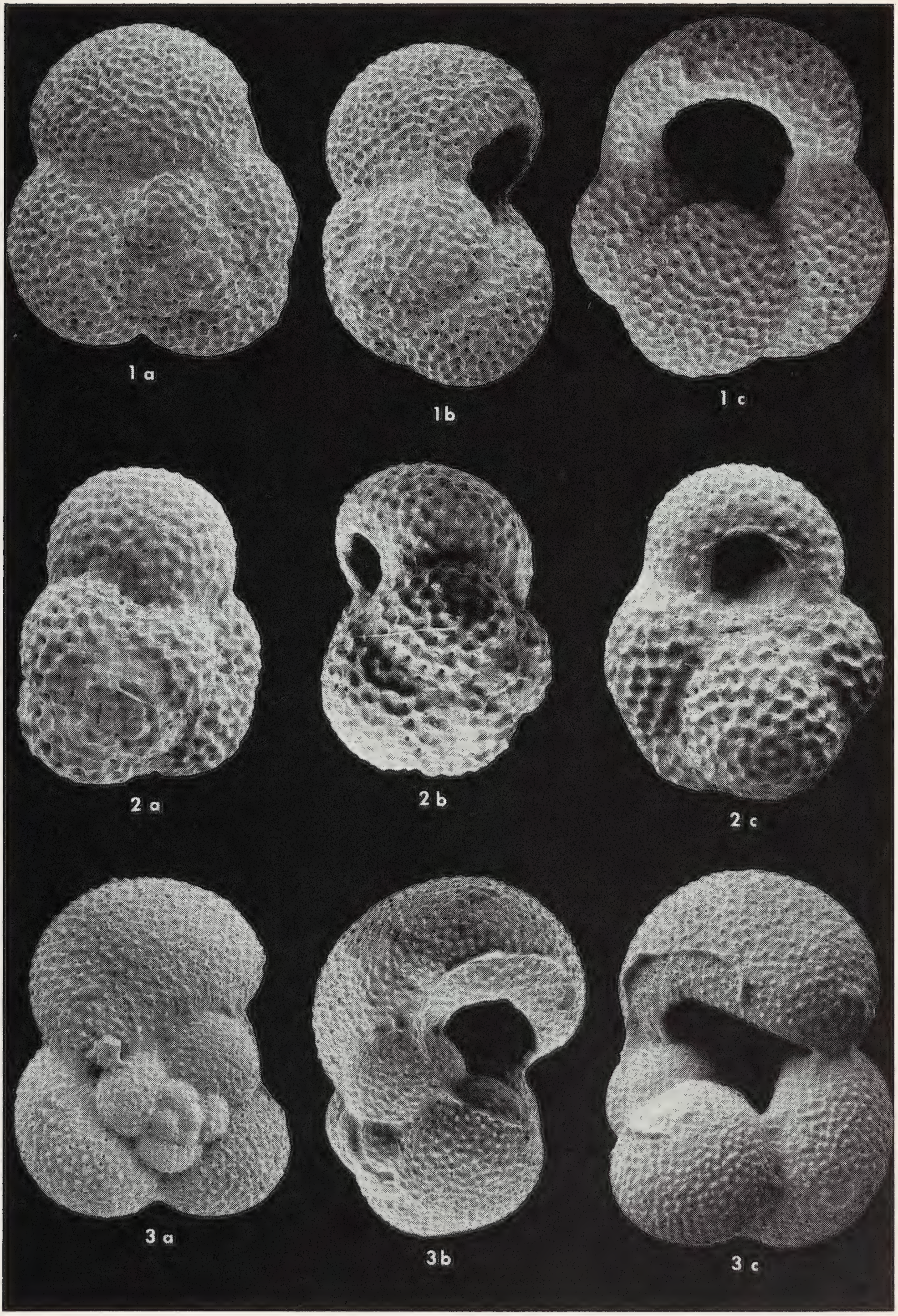


Plate 37

"The large globose test consists of 10 chambers (including the proloculum) arranged in a low trochospire of about two whorls with four chambers in each whorl. The equatorial profile is sub-circular, with a weakly and broadly lobulate equatorial periphery. The axial profile is sub-elliptical, the dorsal side being weakly convex and the ventral side being also convex. The axial periphery is broadly and smoothly rounded. The chambers are appressed, not greatly inflated, but are moderately embracing; in dorsal view they are reniform, becoming much longer circumferentially than broader radially. The sutures are weakly depressed and initially not very distinct. The spiral suture is lobulate and the intercameral sutures are slightly curved to nearly radial, dorsally meeting the spiral suture nearly at right angles. The umbilicus is distinct, moderately broad, quadrate in outline and deep. The primary aperture is a low interiomarginal arch totally confined within the umbilicus. No apertural lip, rim or tooth is visible on the neotype. The apertural face is somewhat flattened; it directly faces the umbilicus and forms a distinct although rounded angle with the remainder of the chamber wall. The wall is coarsely and uniformly perforate. The surface of the test is rough and cancellate, furnished with strong short spines which are particularly well developed along the margins of the umbilicus. Maximum diameter of neotype: 0.75 mm." (Banner and Blow, 1960)

Neotype: British Museum (Natural History) P. 44031; obtained by Schwager from the Pliocene (?) of Kar Nikobar, sent by him to Brady.

*Discussion:* Blow gives the later parts of Zone N. 19 to Zone N. 23 as the range of this species. Together with *Globorotaloides hexagona, Globoquadrina conglomerata* disappeared from the Atlantic-Caribbean Region just prior to Zone N. 22, although both are living in the Indian and Pacific Oceans.

## GLOBOQUADRINA DEHISCENS
## (Chapman, Parr, and Collins)

Pl. 8, fig. 1; Pl. 15, fig. 3

*Globorotalia dehiscens* CHAPMAN, PARR, and COLLINS, 1934, Linn. Soc. London, (Zoology), Jour., vol. 38, no. 262, p. 569, pl. 11, fig. 36.

*Globorotalia quadraria* CUSHMAN and ELLISOR, 1939, Cushman Lab. Foram. Res., Contr., vol. 15, p. 11, pl. 2, fig. 5.

*Globorotalia dehiscens* Chapman, Parr, and Collins. FINLAY and MARWICK, 1940, Roy. Soc. New Zealand, Trans., vol. 70, pp. 114, 123, subsequent lists.

*Globoquadrina subdehiscens* FINLAY, 1947, New Zealand Jour. Sci. Technology, vol. 28, no. 5 (Sec. B), p. 291

*Globoquadrina quadraria* (Cushman and Ellisor) var. *advena* BERMÚDEZ, 1949, Cushman Lab. Foram. Res., Spec. Pub. 25, p. 287, pl. 22, figs. 36-38.

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## PLATE 38
## JACKSON BLUFF FORMATION
## CANCELLARIA FAUNIZONE
## JACKSON BLUFF, BED 10

Figures Page

1. *Globigerinoides obliquus extremus* Bolli and Bermúdez. . . . . 58
Maximum diameter, 0.49 mm
a. Spiral view, X 126
b. Umbilical view, X 126
c. Edge view, X 126

2. *Globigerinita glutinata* (Egger). . . . . 70
Maximum diameter, 0.29 mm
a. Edge view, X 183
b. Spiral view, X 183
c. Umbilical view, X 185

3. *Globigerinoides ruber* (d'Orbigny). . . . . 66
Maximum diameter, 0.52 mm
a. Umbilical view, X 101
b. Spiral view, X 101
c. Edge view, X 101

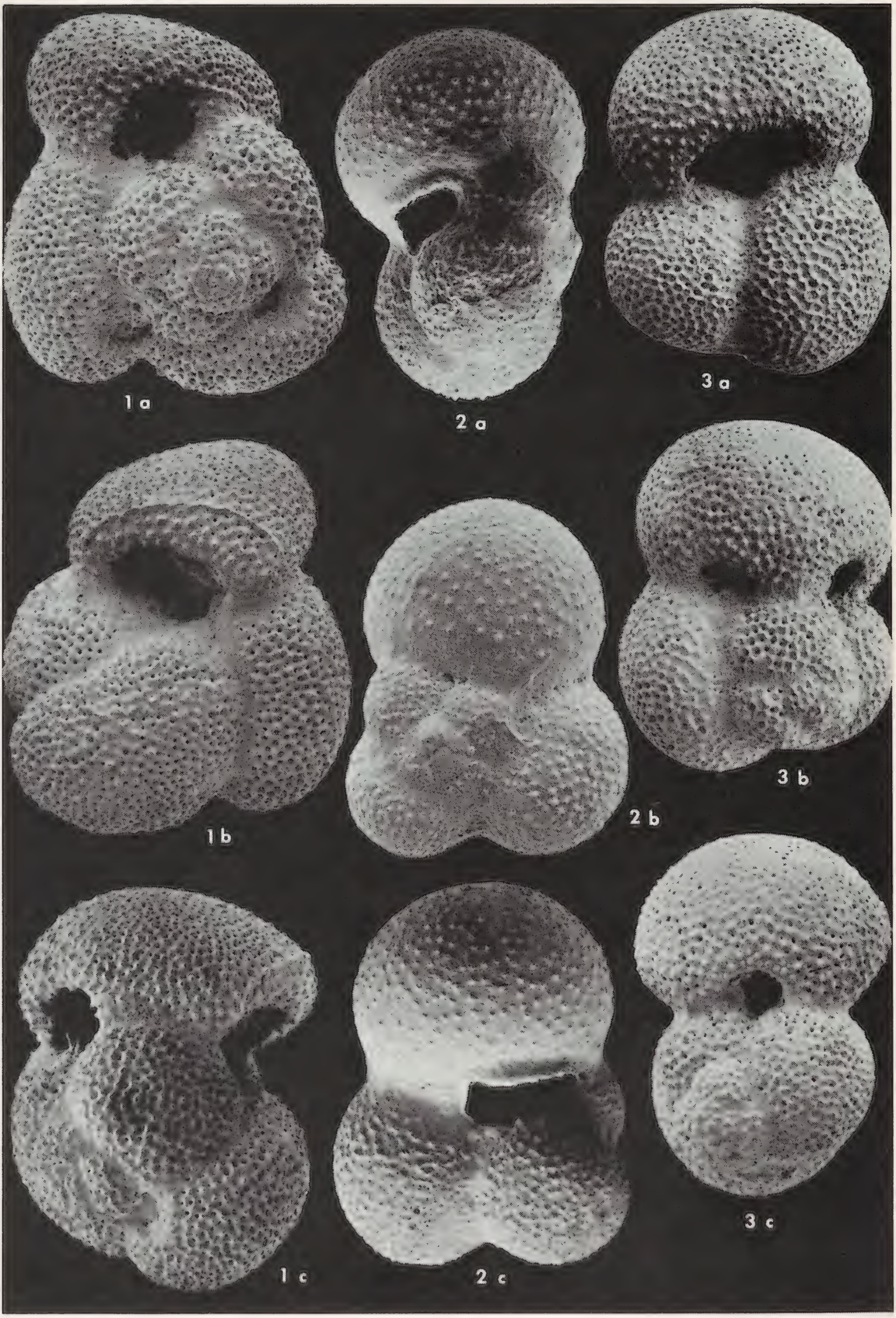


Plate 38

*Globoquadrina dehiscens* (Chapman, Parr, and Collins). PARKER, 1967, Bull. Amer. Paleontology, vol. 52, no. 235, pp. 166-168, pl. 26, figs. 1-3.

"Test subconical, about as broad as high, the dorsal side flattened or slightly convex, the ventral side strongly convex and deeply umbilicate, margin rounded, composed of several whorls with four chambers in the last-formed one, chambers increasing quickly in size and height as added, well inflated, and separated along their inner margins by deep fissures; sutures radial, depressed; surface reticulate or slightly papillate, the apertural face being finely punctate; aperture an elongate slit extending almost the full length of the inner margin of the last-formed chamber and opening into the umbilical cavity. Diameter, 0.55 mm." (Chapman, Parr, and Collins, 1934)

Holotype: Chapman collection; from Kackeraboite Creek, Port Phillip area, Victoria, Australia.

*Discussion:* Cifelli (see Parker, 1967, p. 167) examined the types of Bermúdez' variety and believes that form to be a synonym of the present species. Bermúdez (1961, p. 1.310) concurs with this interpretation. Blow (1969, p. 341) considers the form of Bermúdez to be subspecifically distinct and to have a range from within the later parts of Zone N. 6 to within Zone N. 15, whereas, he records a range from Zone N. 5 to Zone N. 19 for *G. dehiscens s. l.* The writer has not seen sufficient evidence for differentiation, and he has not seen documentation of *G. dehiscens s.l.* above Zone N. 17, as the zone is defined by Blow (1969).

## GLOBOQUADRINA DUTERTREI (d'Orbigny)

Pl. 60, fig. 2

*Globigerina rotundata* D'ORBIGNY, 1826, Ann. Sci. Nat., (ser. 1), vol. 7, p. 277, list no. 6 *(nomen nudum).*

*Globigerina dutertrei* D'ORBIGNY *in* DE LA SAGRA, 1839, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 84, pl. 4, figs. 19-21.

*Globigerina rotundata* d'Orbigny. FORNASINI, 1898, Palaeontographia Italica, vol. 4, p. 208, text-fig. 3.

*Globigerina eggeri* RHUMBLER *in* BRANDT, 1901, Nordisches Plankton, Lief 1, no. 14, p. 19, text-fig. 20 (after Brady, 1884, pl. 79, "*G. dubia* Egger").

*Globigerina subcretacea* LOMNICKI, 1901, Naturf. Ver. Berlin, Abh., vol. 39 (1900), p. 17 [included in synonymy: Brady, 1884, pl. 82, fig. 10 "*G.* (*cretacea* d'Orbigny?)"]

*Globigerina dutertrei* d'Orbigny. BANNER and BLOW, 1960, Cushman Found. Foram. Res., Contr., vol. 11, p. 11, pl. 2, fig. 1 (lectotype).

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## PLATE 39
## JACKSON BLUFF FORMATION
## CANCELLARIA FAUNIZONE
## JACKSON BLUFF, BED 10

Figures

Page

1. *Sphaeroidinellopsis subdehiscens subdehiscens* Blow. . . . . 86
Maximum diameter, 0.34 mm
   a. Spiral view, X 178
   b. Edge view, X 175
   c. Umbilical view, X 175

2. *Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny). . . . . 62
Maximum diameter, 0.59 mm
   a. Edge view, X 90
   b. Umbilical view, X 91
   c. Spiral view, X 90

3. *Sphaeroidinellopsis subdehiscens subdehiscens* Blow. . . . . 86
Maximum diameter, 0.34 mm
   a. Spiral view, X 178. Resolution along suture.
   b. Edge view, X 175
   c. Umbilical view, X 175

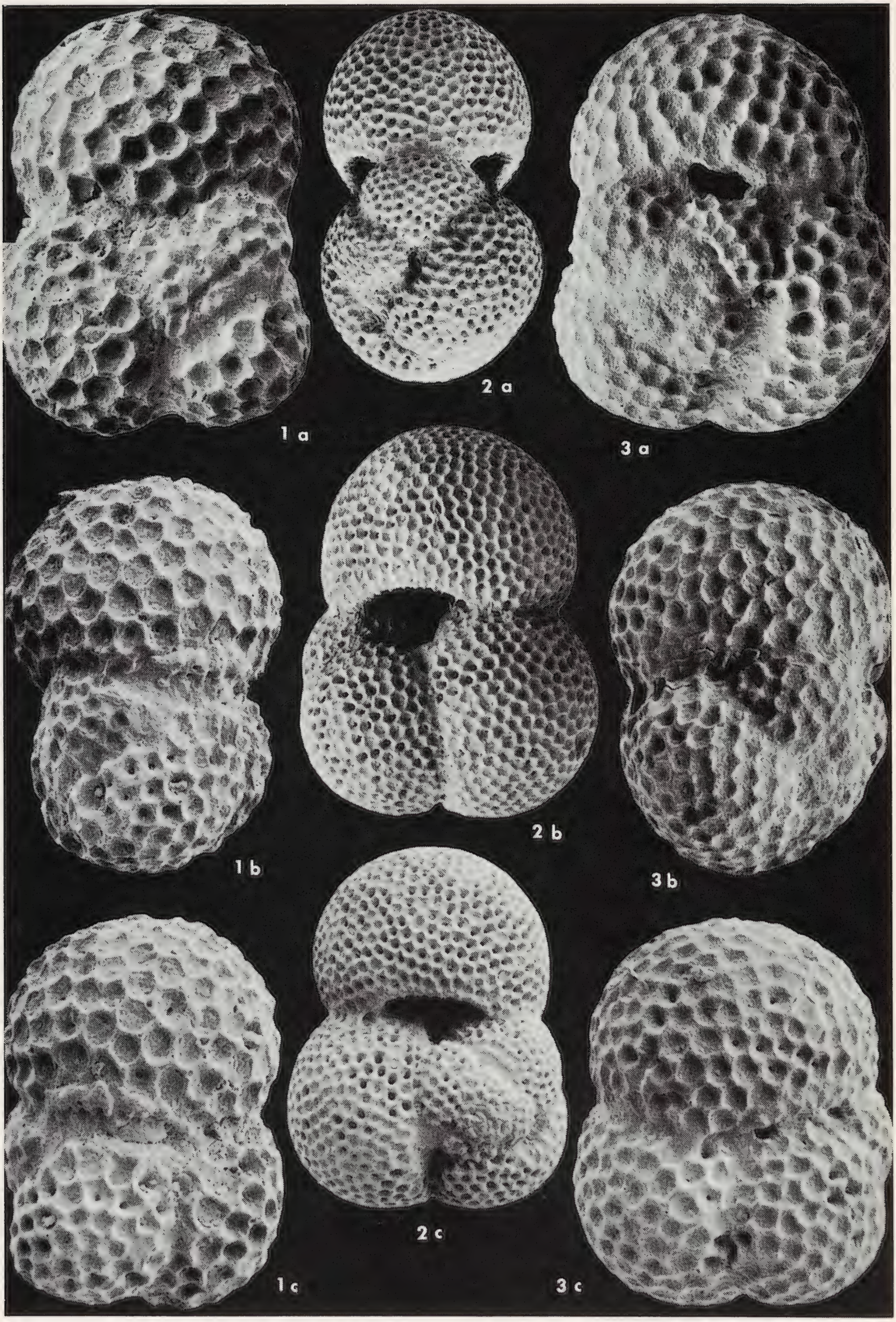


Plate 39

*Globigerina eggeri* Rhumbler. BANNER and BLOW, 1960, Cushman Found. Foram. Res., Contr., vol. 11, p. 11, pl. 2, fig. 4 (lectotype).

*Globigerina rotundata* Fornasini. BANNER and BLOW, 1960, Cushman Found. Foram. Res., Contr., vol. 11, p. 19, pl. 2, fig. 2 (lectotype).

*Globoquadrina dutertrei* (d'Orbigny). PARKER, 1962, Micropaleontology, vol. 8, no. 2, p. 242, pl. 7, figs. 1-13; pl. 8, figs. 1-4.

*Globoquadrina dutertrei* (d'Orbigny). PARKER, 1967, Bull. Amer. Paleontology, vol. 52, no. 235, p. 168, pl. 25, fig. 7.

"*Globigerina*. Testa suborbiculata, convexa, alba, creberrime rugosa, spira convexo-obtusa, anfractibus tribus, distinctis; loculis quinis, oblongatis; suturis excavatis, apertura magna, in umbilico.

"Dimensions: Diamètre 1/2 millim. Coquille globuleuse, discoïde, élevée, partout rugueuse, les rugosités dues au pourtour saillant des nombreux trous dont chaque loge est criblée. Spire convexe, à sommet très obtus, composée de trois tours bien distincts et formée, dans l'état adulte, de dix à douze loges. Loges ovales, dans le sens de l'axe, au nombre de cinq au dernier tour, très séparées, et laissant a leur centre un profond ombilic. Ouverture en croissant, très large, placée sur plus de la moitié de la dernière loge, dans l'ombilic même. Couleur, blanc ou blanc-jaunâtre.

"Par sa spirale bien distincte, composée d'un grand nombre de loges, par les cinq loges de son dernier tour, cette espèce a beaucoup d'analogie avec notre *G. fragilis* fossile, dans les environs de Dax; mais, percée de trous bien plus grands, elle s'en distingue par sa contexture plus poreuse, plus ruguese, et par son ouverture bien plus largement ouverte." (d'Orbigny, 1839)

Holotype: not designated, but d'Orbigny's specimens were from Recent beach sands of Cuba, Martinique, and Guadeloupe.

*Discussion:* The concept of Parker (1962 and 1967) is followed here for this form, since it agrees more with the writer's own experiences and opinions than does the concept of Blow (1969, p. 318), who recognizes two distinct taxa, *Globigerina dutertrei* d'Orbigny and *Globigerina eggeri eggeri* Rhumbler. Blow believes that these are derived from a third form, *Globigerina eggeri multiloba* Romeo, whereas Parker and the writer consider *Globoquadrina dutertrei* to have developed from *Globorotalia (T.) acostaensis humerosa.* Forms included here under *Globoquadrina dutertrei* range from Zone N. 19 to Zone N. 23 according to Blow, however Parker (1967, p. 168) and the writer cannot document the taxon below Zone N. 21.

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## PLATE 40
## JACKSON BLUFF FORMATION
## CANCELLARIA FAUNIZONE
## JACKSON BLUFF, BED 10

Figures Page

1. *Globoquadrina altispira globosa* Bolli. . . . . 88
Maximum diameter, 0.46 mm
   a. Spiral view, X 129
   b. Edge view, X 127
   c. Umbilical view, X 127

2. *Globorotalia (Turborotalia) acostaensis humerosa* Takayanagi and Saito. . . . . 108
Maximum diameter, 0.42 mm
   a. Spiral view, X 126
   b. Edge view, X 126
   c. Umbilical view, X 126

3. *Globorotalia (Globorotalia) cultrata* subsp. . . . . 22
Maximum diameter, 0.30 mm
   a. Edge view, X 166
   b. Spiral view, X 168
   c. Umbilical view, X 166

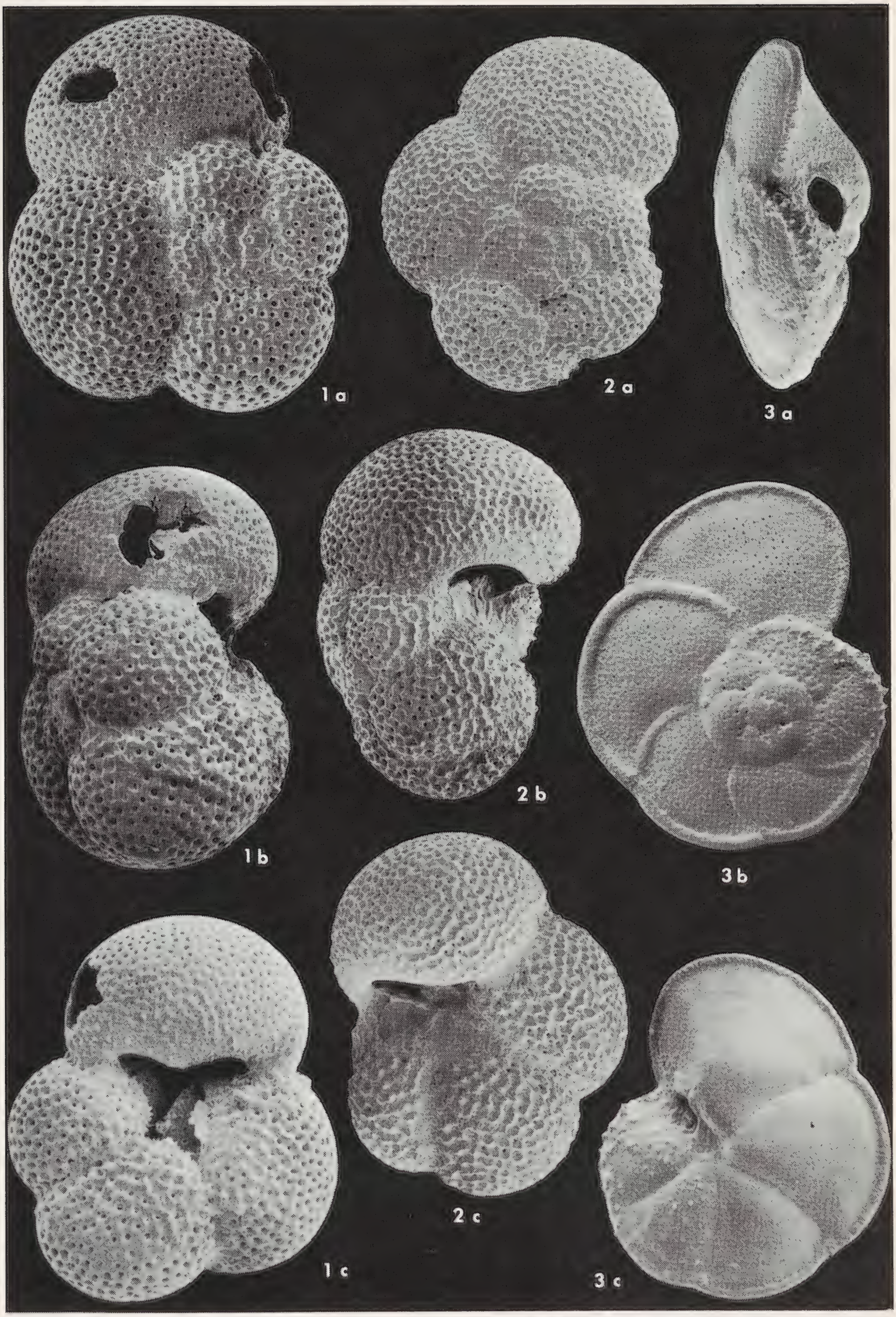


Plate 40

## Family GLOBOROTALIIDAE Cushman, 1927

## Genus GLOBOROTALIA Cushman, 1927

### GLOBOROTALIA (GLOBOROTALIA) CULTRATA LIMBATA (Fornasini)

Pl. 33, fig. 2

*Rotalia limbata* D'ORBIGNY, 1826, Ann. Sci. Nat., (ser. 1), vol. 7, p. 274, list no. 3 *(nomen nudum)*.

*Rotalia limbata* D'ORBIGNY *in* FORNASINI, 1902, Roy. Acad. Sci. Ist. Bologna, Mem. Sci. Nat. Bologna, ser. 5, vol. 10, p. 56, text-fig. 55, ("disegno inedito"); (lectotype of Banner and Blow, 1960).

*Rotalia limbata* d'Orbigny. BANNER and BLOW, 1960, Cushman Found. Foram. Res., Contr., vol. 11, pt. 1, pp. 30-31, pl. 5, figs. 3a-c (lectotype designated).

*Globorotalia (Globorotalia) cultrata limbata* (Fornasini). BLOW, 1969, Proc. First International Conference on Planktonic Microfossils, vol. 1, p. 359, pl. 7, figs. 4-6; pl. 42, figs. 2, 3.

"The test consists of 14 chambers arranged in about 2 1/2 whorls comprising a low trochospire with 6 chambers present in the last whorl. The equatorial profile is sub-circular and the equatorial periphery is moderately lobulate. The axial profile is rhomboidal with an acute carinate periphery. The test is somewhat compressed dorso-ventrally and is almost equally biconvex. The chambers are uniformly and regularly enlarging (with the exception of the abnormally reduced final chamber); in dorsal aspect they are semi-circular, little inflated and do not embrace. In ventral view the chambers are sub-triangular, slightly inflated and partially embracing. The dorsal sutures are slightly depressed and are limbate, being thickened by a deposit of clear shell material which is continuous with the imperforate peripheral carina. The dorsal intercameral sutures are, for the most part, smoothly curved but in the last few chambers they become angular. These sutures meet the spiral suture at right angles and recurve to become almost tangential to the periphery. The ventral intercameral sutures are depressed, not thickened or limbate, but are slightly curved or slightly sinuous and become nearly radial. The umbilicus is small, open and fairly deep. The primary aperture is a low interiomarginal arch, extending from the umbilicus almost to the periphery; it possesses a thin and narrow lip along its length. The apertural face is sub-triangular in apertural view and is only slightly flattened, not being clearly delimited from the ventral face of the last chamber. The umbilical shoulders of the ventral surfaces of the chambers are weakly developed. The wall is finely and uniformly perforate, except for the areas of the imperforate peripheral carina and the dorsal sutural limbations. The surface of the test is smooth except for a weakly developed pustulose area on the ventral side of the first chamber of the last whorl, facing the primary aperture. Maximum diameter of lectotype: 0.44 mm. The lectotype has suffered slight damage and parts of the periphery of the last two chambers have been lost." (Banner and Blow, 1960)

Lectotype: d'Orbigny Collection, Muséum National de l'Histoire Naturelle, Paris; Recent deposits of the Adriatic near Rimini.

*Discussion:* Range is from Zone N. 13 or N. 14 to Zone N. 21 (Blow, 1969).

### GLOBOROTALIA (GLOBOROTALIA) CULTRATA MENARDII (Parker, Jones and Brady)

Pl. 9, fig. 2; Pl. 13, fig. 1; Pl. 17, fig. 2; Pl. 55, fig. 3

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## PLATE 41
## JACKSON BLUFF FORMATION ?
## CANCELLARIA FAUNIZONE ?
## R. L. GAINER FARM

Figures Page

1. *Globigerina bulloides bulloides* d'Orbigny. . . . . 48
   Maximum diameter, 0.34 mm
   - a. Spiral view, X 179
   - b. Edge view, X 175
   - c. Umbilical view, X 179

2. *Turborotalita quinqueloba* (Natland). . . . . 122
   Maximum diameter, 0.23 mm
   - a. Edge view, X 315
   - b. Spiral view, X 308
   - c. Umbilical view, X 311

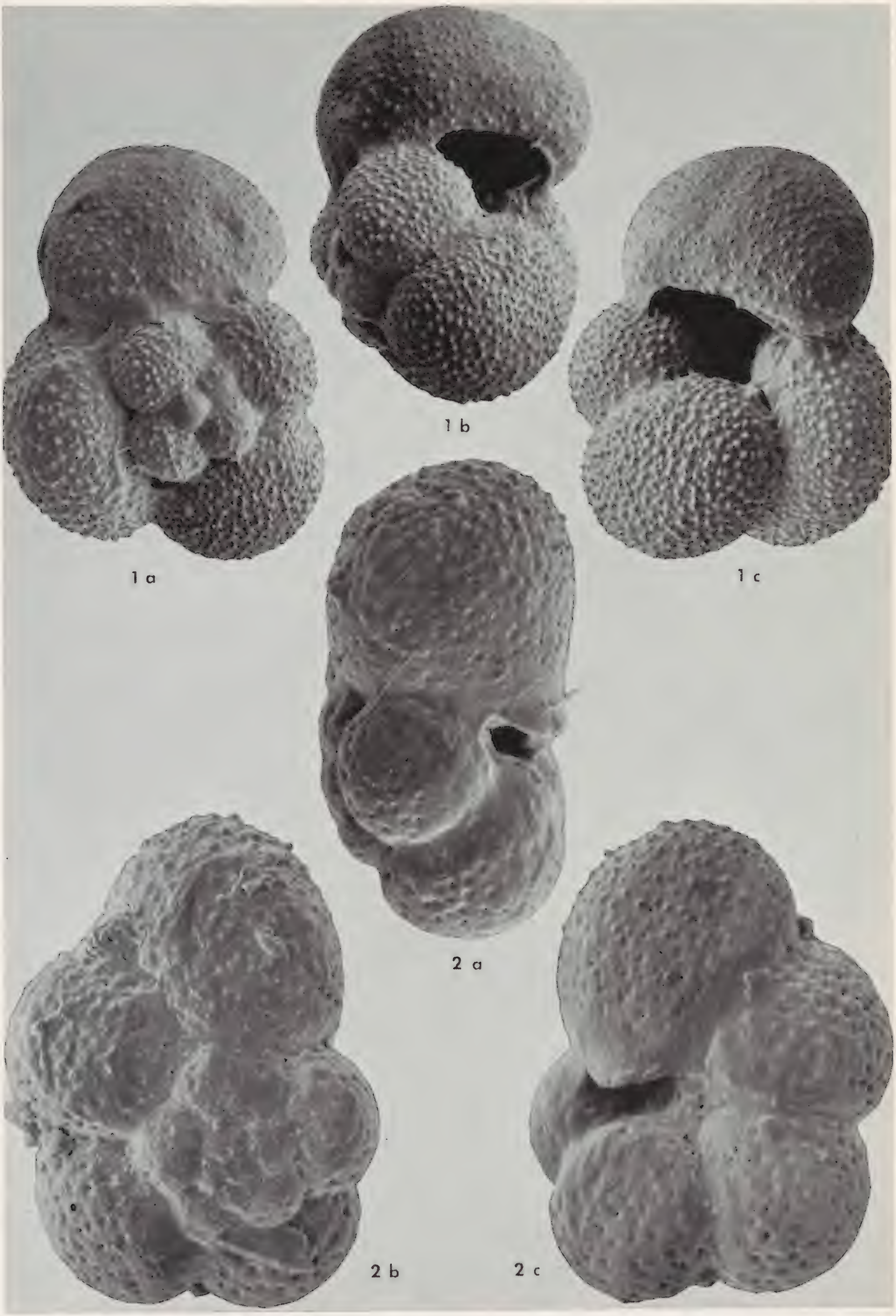


Plate 41

*Rotalia (Rotalie) menardii* D'ORBIGNY, 1826, Ann. Sci. Nat., Paris, (ser. 1), vol. 7, p. 273, list no. 26, *(nomen nudum)* (*teste* Parker, Jones and Brady, 1865).

*Rotalia menardii* PARKER, JONES and BRADY, 1865, Ann. Mag. Nat. Hist., (ser. 3), vol. 16, p. 20, pl. 3; fig. 81; (lectotype of Banner and Blow, 1960).

*Rotalia menardii* Parker, Jones and Brady. BANNER and BLOW, 1960, Cushman Found. Foram. Res., Contr., vol. 11, pt. 1, p. 31, pl. 6, figs. 2a-c; (lectotype designated).

*Globorotalia (Globorotalia) cultrata menardii* (Parker, Jones and Brady). BLOW, 1969, Proc. First International Conference on Planktonic Microfossils, vol. 1, pp. 359-360, pl. 6, figs. 9-11.

"The fairly large test consist of about 3 whorls of fairly rapidly enlarging chambers arranged in a moderately low trochospire. There are about 5 1/2 chambers present in the last whorl (the final chamber being damaged peripherally). The equatorial profile of the test is subcircular and its equatorial periphery is moderately lobulate. In axial profile the test is moderately compressed, being almost equally biconvex and the axial periphery is acute and strongly carinate. In dorsal aspect the chambers are weakly inflated and are little, if at all, embracing; the chambers are nearly as long circumferentially as they are broad radially. The dorsal sutures are slightly depressed and are thickened with a deposit of clear shell material which appears to be continuous with the peripheral imperforate carina. The inner (proximal) ends of the dorsal intercameral sutures meet the moderately lobulate spiral suture almost at right angles, while they become smoothly recurved distally to meet the periphery almost tangentially. In ventral aspect the chambers are sub-triangular and moderately inflated. The ventral intercameral sutures are depressed, not thickened or limbate, and are nearly radial being slightly curved to sinuous. The umbilicus is small (compared to overall test size), but it is open and deep. The inner parts of the ventral chamber sides form inconspicuous umbilical shoulders. The primary aperture is interiomarginal, umbilical-extraumbilical, a moderately high arch extending for the full length of the ventral basal suture of the final chamber. The primary aperture is furnished, along its length, with a uniformly developed thin, but hispid, lip. Relict parts of the apertures of the later chambers of the last whorl, together with their lips, may be seen within the umbilicus. The apertural face of the terminal chamber is slightly flattened although there is no angular delimitation between it and the adjacent ventral face; the apertural face is limited peripherally by a slender continuation of the carina and the face becomes slightly concave in the vicinity of it. The wall is finely perforate except in the imperforate regions of the dorsal sutures and the peripheral carina. The surface of the test is smooth except for weakly hispid areas on the ventral faces of the first two chambers of the last whorl and the adjacent parts of the carina. Maximum diameter of lectotype: 0.76 mm." (Banner and Blow, 1960)

The following distinctions are worthy of repetition here:

"Many authors have supposed that "*Globorotalia menardii* D'ORBIGNY" (*vel* PARKER, JONES, and BRADY 1865) is a full senior synonym of "*Globorotalia cultrata* D'ORBIGNY, 1839"; however, this is not so and the two morphotypes can be recognized. Thus, *G. (G.) cultrata cultrata* possesses a flat, equally biconvex test with the spire opening slowly and regularly. The chambers do not increase rapidly as added and the dorsal intercameral sutures follow a smooth, almost hemi-circular path from the dorsal spiral suture to the peripheral point of attachment of the chamber to its predecessor. On the other hand, *G. (G.) cultrata menardii,* has an unequally biconvex

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PLATE 42
JACKSON BLUFF FORMATION ?
CANCELLARIA FAUNIZONE ?
R. L. GAINER FARM

Figures Page

1. *Globigerina bulloides apertura* Cushman. . . . . 46
Maximum diameter, 0.43 mm
   a. Spiral view, X 159
   b. Umbilical view, X 159
   c. Edge view, X 154

2. *Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny). . . . . 62
Maximum diameter, 0.58 mm
   a. Spiral view, X 101
   b. Umbilical view, X 101
   c. Edge view, X 101

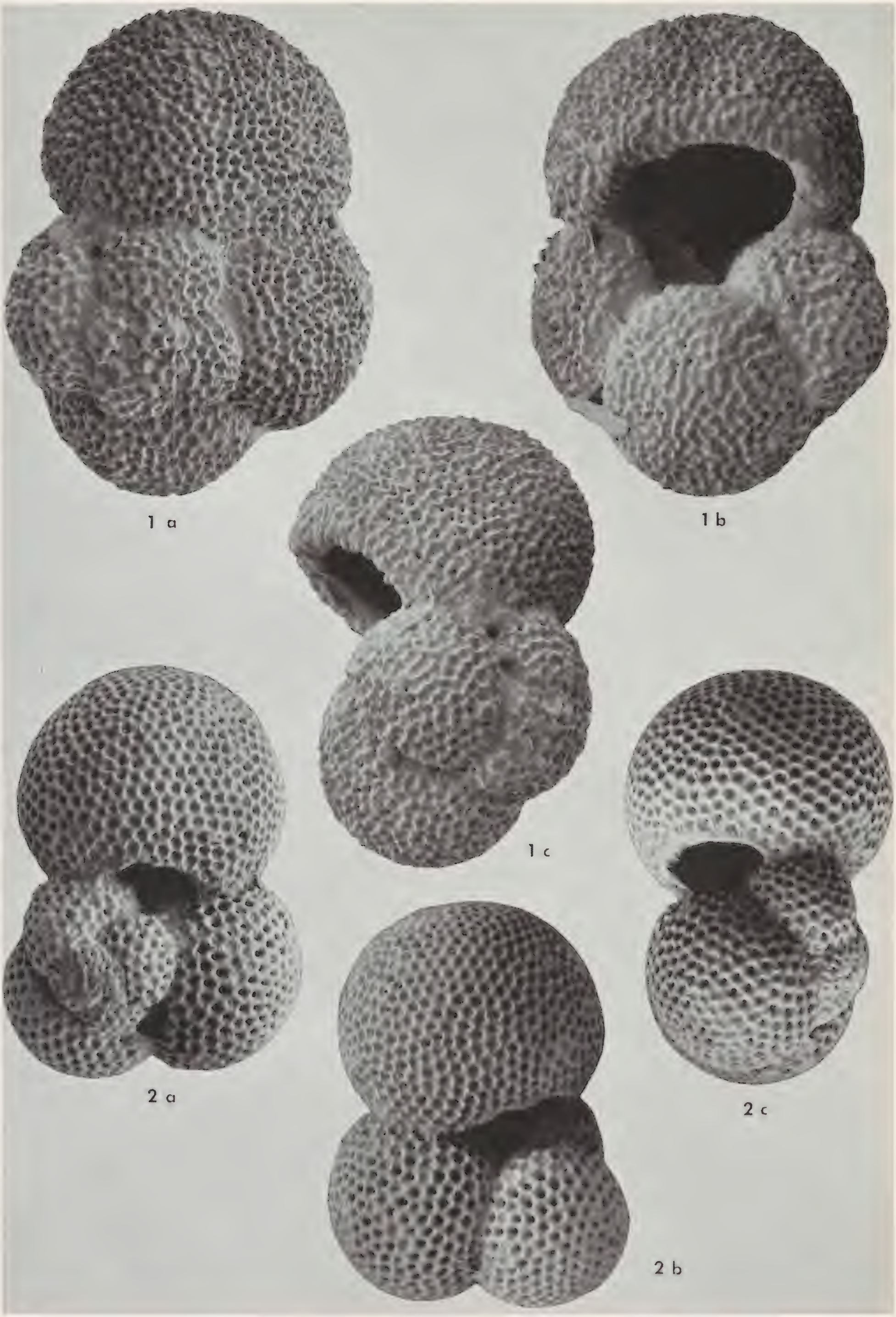


Plate 42

test which is distinctly more vaulted and inflated ventrally than dorsally. Further, in *menardii* the spire opens rapidly and, consequently, the chambers increase rapidly in size as added in the progression of the trochospire; the dorsal intercameral sutures are not smoothly hemi-circular but show a break in their curvature so that there is an approach to a "hockey-stick" shape." (Blow, 1969).

Lectotype: British Museum (Natural History) 1959.7.27.3; obtained by H. B. Brady from Recent marine sediments, at 15 fathoms depth off Laxey, Isle of Man, Irish Sea.

*Discussion:* The range given for this form by Blow is from within Zone N. 14 (?Zone N. 13) to Zone N. 23.

## GLOBOROTALIA (GLOBOROTALIA) MARGARITAE Bolli and Bermúdez

Pl. 19, fig. 4; Pl. 32, fig. 1;
Pl. 33, fig. 1

*Globorotalia (G.) margaritae* BOLLI and BERMÚDEZ, 1965, Boletin Informativo, Asociacion Venezolana de Geologia, Min. y Pet., vol. 8, no. 5, pp. 139-140, pl. 1, figs. 16-18.

*Globorotalia* cf. *canariensis* (d'Orbigny). BLOW, 1959, Bull. Amer. Paleontology, vol. 39, no. 178, p. 211, pl. 17, figs. 109a-c.

*Globorotalia margaritae* Bolli and Bermúdez. PARKER, 1967, Bull. Amer. Paleontology, vol. 52, no. 235, pp. 179-180, pl. 32, figs. 1, 2.

*Globorotalia (Globorotalia) margaritae* Bolli and Bermúdez. BLOW, 1969, Proc. First International Conference on Planktonic Microfossils, vol. 1, pp. 363-364, pl. 45, figs. 1-3, 5-6; pl. 44, figs. 1-6.

"Shape of test low trochospiral, compressed and elongate; equatorial periphery slightly lobate; axial periphery acute with a thin keel. Spiral side rounded-convex; umbilical side much less convex. Wall calcareous, finely perforate, surface smooth to very finely pitted. Chambers strongly compressed, seen from the spiral side elongate, fairly narrow and distinctly curved, about 12, arranged in 2 to 2 1/2 whorls; the usually 5 chambers of the last whorl increase fairly rapidly in size. Sutures on spiral side strongly curved but only very slightly depressed; on umbilical side radial to slightly curved, more or less depressed. Umbilicus very narrow. Aperture a slit, bordered above by a small, thin lip, interiomarginal, umbilical-extraumbilical. Coiling sinistral. Largest diameter of holotype: 0.37 mm." (Bolli and Bermúdez, 1965)

Holotype: lost, but H. Bolli is substituting a neotype for this taxon (*teste* R. Cifelli, *fide* Blow, 1969, p. 363).

*Discussion:* The specimen illustrated, pl. 19, fig. 4, is an immature one, but forms from Alum Bluff, Bed 4, though small, are typical in all other respects. A larger, but broken specimen was found from this locality, in addition to several immature individuals. Range: from within the middle to later parts of Zone N. 16 to within Zone N. 19 (Blow, 1969).

## GLOBOROTALIA (GLOBOROTALIA) MIOCENICA Palmer

*Globorotalia menardii* (d'Orbigny) *miocenica* PALMER, 1945, Bull. Amer. Paleontology, vol. 29, no. 115, p. 70, pl. 1, fig. 10.

*Globorotalia (Globorotalia) miocenica* Palmer. BLOW, 1969, Proc. First International Conference on Planktonic Microfossils, vol. 1, pp. 365-366, pl. 8, figs. 10-12; pl. 42, figs. 4, 8.

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## PLATE 43
## JACKSON BLUFF FORMATION ?
## CANCELLARIA FAUNIZONE ?
## R. L. GAINER FARM

Figures Page

1. *Globigerinoides obliquus extremus* Bolli and Bermúdez. . . . . 58
   Maximum diameter, 0.44 mm
   a. Spiral view, X 143
   b. Edge view, X 143
   c. Umbilical view, X 144

2. *Globigerinoides ruber* (d'Orbigny). . . . . 66
   Maximum diameter, 0.53 mm
   a. Spiral view, X 125
   b. Umbilical view, X 125

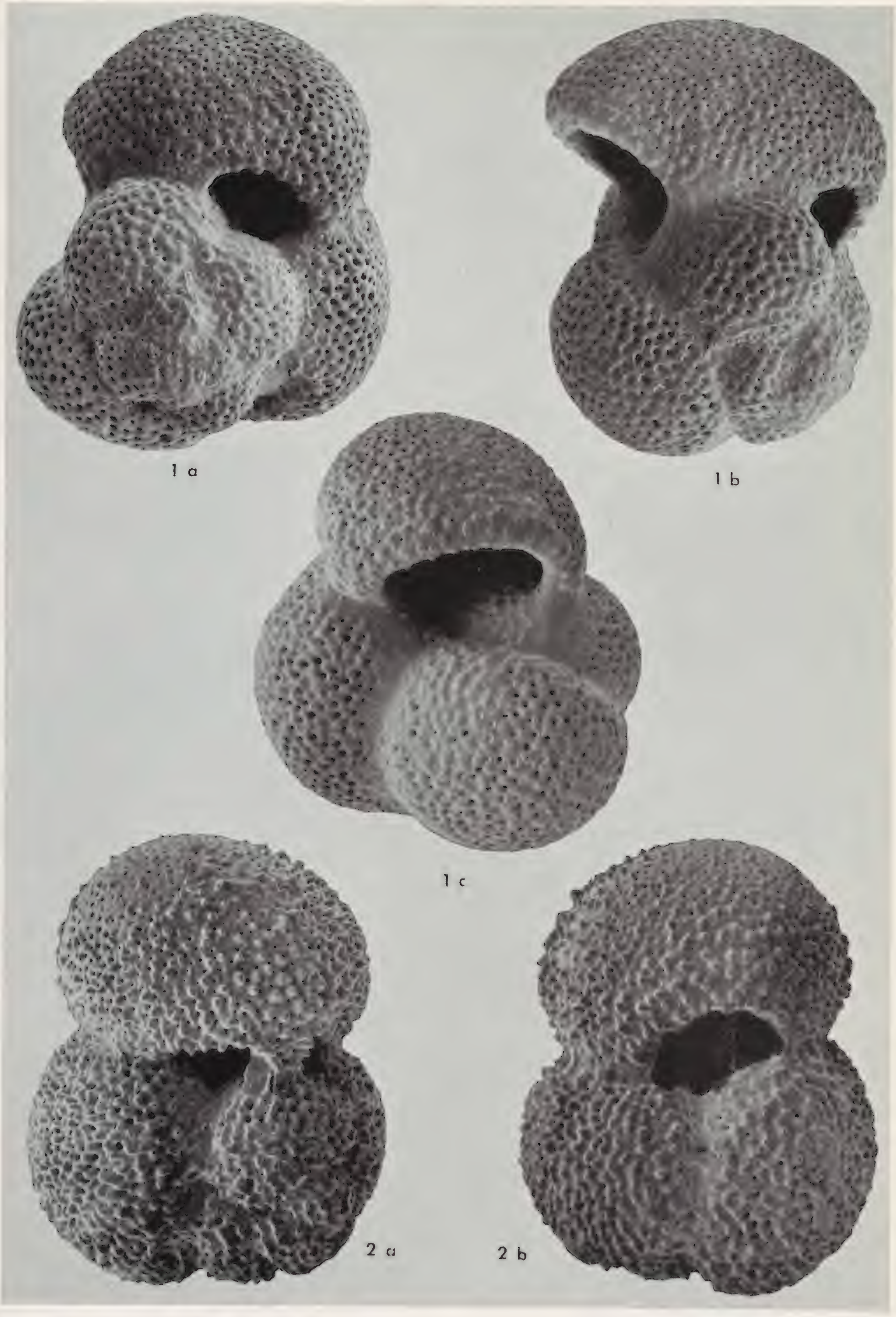


Plate 43

"Test of average size; dorsally flat; ventrally strongly convex; composed of 2 1/2 whorls with about six chambers in the final whorl; dorsal sutures broadly curved, clear, limbate but not generally elevated; spiral suture and periphery with limbate, elevated border; ventral sutures radial, depressed; ventrally the chambers terminate in a small, open umbilical depression. Aperture extending from the umbilical depression to the periphery on the inner base of the final chamber. Surface very finely but distinctly perforate. Maximum diameter of holotype, 0.6 mm; height, 0.02 mm." (Palmer, 1945)

Holotype: Paleontological Research Institution, Ithaca, New York, 20047; Bowden, near Port Morant, Jamaica, at foot of hill where road to old Capt. Baker house turns off the main road to Bowden P. O. and the United Fruit Co. wharf.

*Discussion:* The range is from the middle part of Zone N. 17 to within the early part of Zone N. 21, according to Blow. This form appears to be restricted to the Atlantic Province (the Gulf of Mexico and Caribbean areas and in deep-sea cores in the Atlantic Ocean). So far, it has not been reported from Pacific regions.

## GLOBOROTALIA (GLOBOROTALIA) MULTICAMERATA Cushman and Jarvis

Pl. 19, fig. 2; Pl. 46, fig. 1

*Globorotalia menardii* (d'Orbigny) var. *multicamerata* CUSHMAN and JARVIS, 1930, Jour. Paleontology, vol. 4, p. 367, pl. 34, fig. 8.

*Globorotalia (Globorotalia) multicamerata* Cushman and Jarvis. BLOW, 1969, Proc. First International Conference on Planktonic Microfossils, vol. 1, p. 367-368, pl. 7, figs. 7-9; pl. 42, fig. 7.

"Variety differing from the typical in the large number of chambers, more distinctly umbilical depression on the ventral side and the very heavy development of the peripheral keel." (Cushman and Jarvis, 1930)

Holotype: USNM 14129; from 1/2 mile east of Buff Bay, Jamaica.

*Discussion:* Range, according to Blow, is from within the middle part of Zone N. 17 to within the early to middle part of Zone N. 21. Some workers consider *Globorotalia menardii* var. *fijiensis* Cushman as a synonym of this form. The writer has seen hundreds of specimens from the Suva Formation of Fiji and regards this form, which is marked by a lobate periphery, as a subspecies of *Globorotalia (G.) multicamerata.*

## GLOBOROTALIA (GLOBOROTALIA) TRUNCATULINOIDES (d'Orbigny)

Pl. 55, fig. 1

*Rotalina truncatulinoides* D'ORBIGNY *in* BARKER-WEBB and BERTHELOT, 1839, Hist. Nat. Îles Canaries, "Foraminifères," vol. 2, pt. 2, pl. 132, pl. 2, figs. 25-27.

*Globorotalia (Globorotalia) truncatulinoides* (d'Orbigny). BLOW, 1969, Proc. First International Conference on Planktonic Microfossils, vol. 1, pp. 403-405, pl. 5, figs. 10-12 (neotype); pl. 49, fig. 6.

"Test coiled in a low trochospire with about 15 chambers comprising the spire and with 5 complete

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## PLATE 44
## JACKSON BLUFF FORMATION ?
## CANCELLARIA FAUNIZONE ?
## R. L. GAINER FARM

Figures Page

1. *Globoquadrina altispira altispira* (Cushman and Jarvis). . . . . 86
   Maximum diameter, 0.43 mm
   a. Spiral view, X 143
   b. Edge view, X 143
   c. Umbilical view, X 143

2. *Globorotalia (Turborotalia) acostaensis humerosa* Takayanagi and Saito. . . . . 108
   Maximum diameter, 0.47 mm
   a. Spiral view, X 134
   b. Umbilical view, X 134
   c. Edge view, X 134

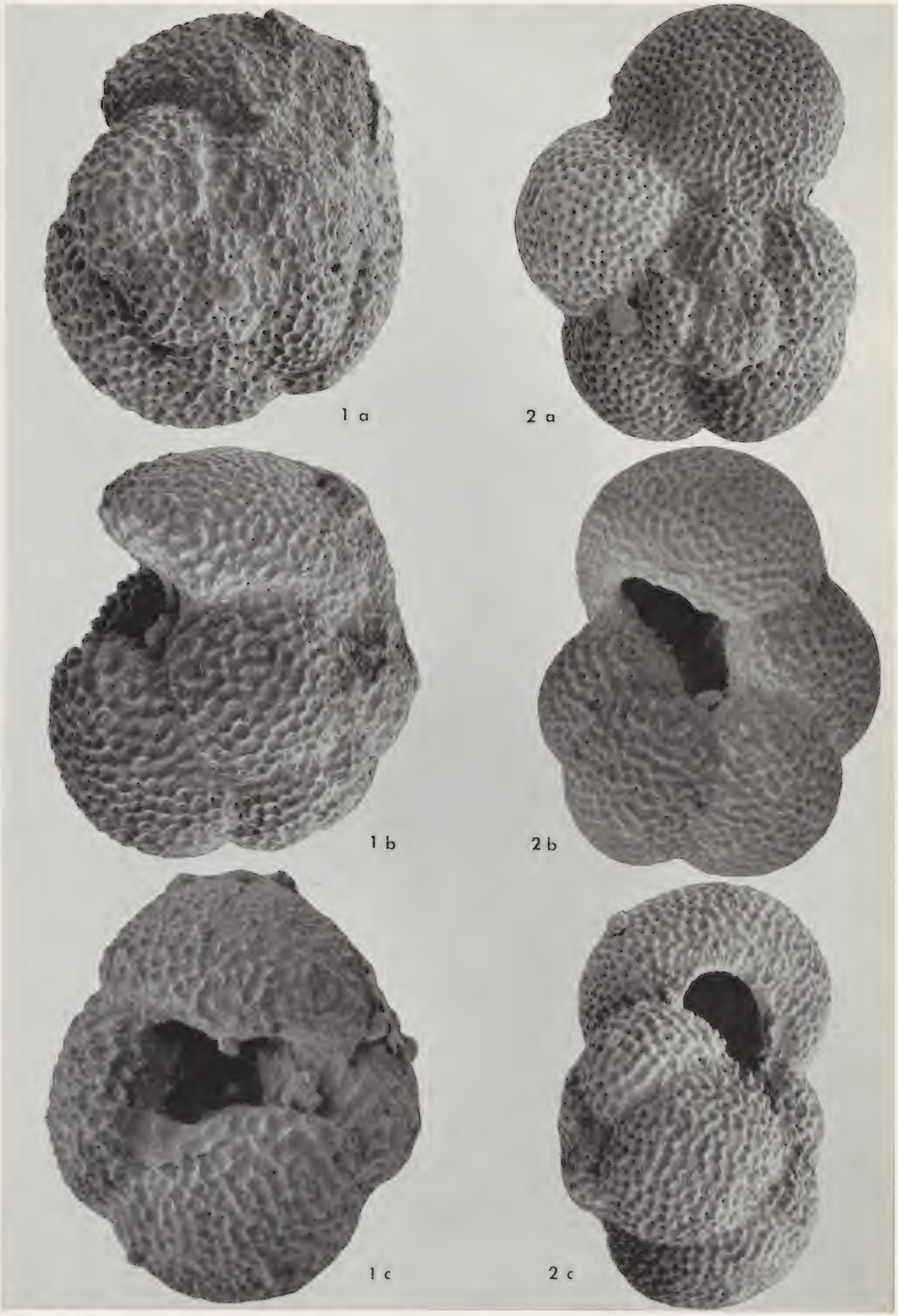


Plate 44

chambers in the last whorl; a small part of a sixth chamber is also visible in the last whorl. Dorsal side of the test flat to slightly concave; ventral side of the test strongly vaulted, acutely conical, so giving an essentially plano-convex test with a distinct carina in axial profile. In equatorial profile the test is not lobulate but almost polygonal in outline with the peripheral margins of the chambers almost flat not strongly curved. In dorsal aspect the chambers are closely appressed but not greatly embracing and not inflated. Dorsal intercameral sutures, radial, virtually straight except for slight retortion at their distal ends; dorsal sutures, slightly limbate and raised. Ventral intercameral sutures slightly incised, distinct, radial to sinuous peripherally. Ventral surfaces of the chambers not significantly inflated, rather compressed and appressed. Umbilicus deep, moderately widely open and sharply delimited by the sudden "in turning" of the umbilical shoulders of the enclosing chambers. The umbilical shoulders of the chambers are pointed and bear pustules. Aperture, interiomarginal, umbilical-extraumbilical, a low arch strictly limited to the basal suture ventral to the carina. Aperture bordered by an asymmetrical lip which is widest at its umbilical end. Relict apertures visible within the umbilicus and the umbilical ends of the earlier apertural lips are also visible. Wall calcareous, radial hyaline, densely but comparatively fine perforate except on the apertural face of the final chamber. The wall is strongly pustulose over the first three chambers of the final whorl immediately adjacent to the aperture. The pustules are densely packed but not fused together, each pustule being clearly delimited and separated one from the other. Pustules also present over the umbilical shoulders of the chambers of the last convolution and over the dorsal surfaces of the chambers of the penultimate whorl. The pores open between the pustules so that there is no significant area of the test without the normal wall-pores which have unrestricted access to the exterior; the pores do not open into pore-pits and do not seem to be modified in any way. Maximum diameter of holotype, 0.78 mm." (Blow, 1969)

Neotype: British Museum (Natural History) 1968.3.27.2; off Gomera, Canary Islands.

*Discussion:* This form ranges from the base of Zone N. 22 to Zone N. 23, according to Blow. Rare but typical specimens were found in the Waccamaw Formation at TU 875.

## Subgenus TURBOROTALIA Cushman and Bermúdez, 1949

### GLOBOROTALIA (TURBOROTALIA) ACOSTAENSIS ACOSTAENSIS Blow

Pl. 17, fig. 1

*Globorotalia acostaensis* BLOW, 1959, Bull. Amer. Paleontology, vol. 39, no. 178, pp. 208-210, pl. 17, figs. 106a-c, 107.

*Globoquadrina acostaensis* (Blow). PARKER, 1967, Bull. Amer. Paleontology, vol. 52, no. 235, pp. 164-165, pl. 24, figs. 3-9.

*Globorotalia (Turborotalia) acostaensis* Blow. BANNER and BLOW, 1967, Micropaleontology, vol. 13, no. 2, p. 153, pl. 3, fig. 1.

*Globorotalia (Turborotalia) acostaensis acostaensis* Blow. BLOW, 1969, Proc. First International Conference on Planktonic Microfossils, vol. 1, pp. 344-345, pl. 9, figs. 13-15; pl. 33, figs. 1, 2.

"Test low trochospiral; spire opening regularly but fairly rapidly, with 11-13 chambers composing the spire, usually with 5-6 chambers in the last whorl. Equatorial periphery strongly lobate, with the test appearing subcircular in equatorial profile; axial periphery rounded with the test appearing

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PLATE 45

JACKSON BLUFF FORMATION ?
CANCELLARIA FAUNIZONE ?
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Figures Page

1. *Turborotalita quinqueloba* (Natland). . . . . 122
Maximum diameter, 0.22 mm
   a. Spiral view, X 210
   b. Edge view, X 203
   c. Umbilical view, X 210

2. *Sphaeroidinella dehiscens dehiscens* (Parker and Jones). . . . . 78
Maximum diameter, 0.56 mm
   a. Umbilical view, X 125
   b. Spiral view, X 125
   c. Edge view, X 125

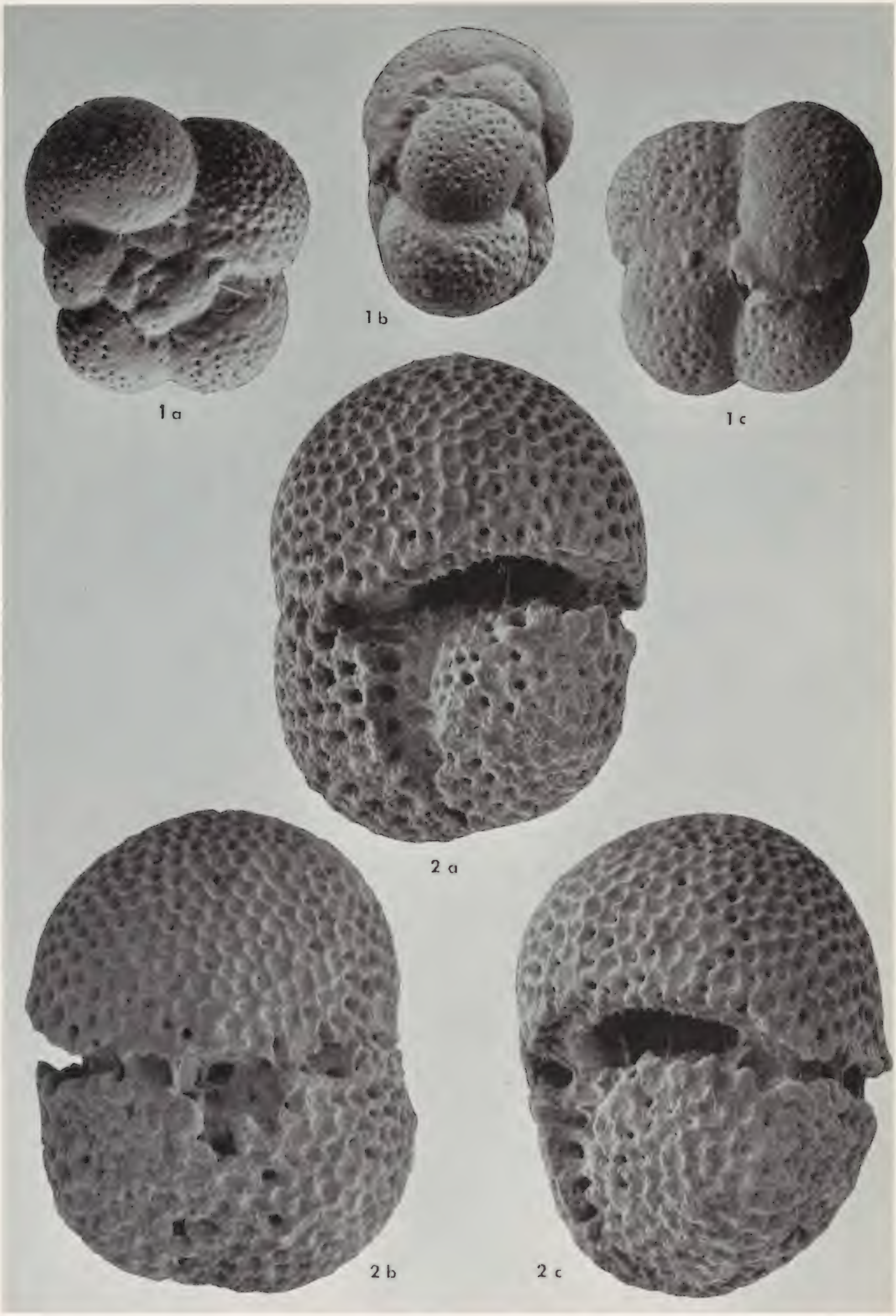


Plate 45

thick and parallel-sided in side view; chambers ovate or subspherical, generally inflated but not well separated; often the last chamber is much reduced in size compared with its predecessor, and it also occasionally becomes somewhat displaced towards the umbilical side. Spiral side slightly convex, almost flat, or occasionally slightly concave due to the inflated nature of the chambers of the last whorl. Umbilical side generally slightly convex, with a small but usually deep umbilicus; sutures of the spiral and umbilical sides radial, depressed; aperture interiomarginal, umbilical-extraumbilical, arched, with a distinctive lip. Maximum diameter of holotype, 0.36 mm." (Blow, 1959)

Holotype: USNM 625707; Pozón Formation, near Pozón, eastern Falcón, Venezuela.

*Discussion:* The range, according to Blow, is from Zone N. 16 to Zone N. 21. Parker has found this form in Indo-Pacific deep-sea cores where it is variable, showing features of the genus *Globoquadrina.* Specimens were found at Blount's Creek and in the Agueguexquite Formation at TU 638.

GLOBOROTALIA (TURBOROTALIA)
ACOSTAENSIS HUMEROSA
Takayanagi and Saito

Pl. 17, fig. 4; Pl. 19, fig. 3;
Pl. 25, fig. 2; Pl. 26, fig. 3;
Pl. 28, fig. 2; Pl. 36, fig. 2;
Pl. 40, fig. 2; Pl. 44, fig. 2;
Pl. 48, fig. 1; Pl. 54, fig. 2;
Pl. 57, fig. 1

*Globorotalia humerosa* TAKAYANAGI and SAITO, 1962, Sci. Repts., Tohoku Univ., 2d ser. (Geology), Spec. Vol., No. 5, p. 78, pl. 28, figs. 1, 2.

*Globoquadrina humerosa* (Takayanagi and Saito). PARKER, 1967, Bull. Amer. Paleontology, vol. 52, no. 235, pp. 196-170, pl. 24, figs. 10, 11; pl. 25, figs. 1-6.

*Globorotalia (Turborotalia) acostaensis humerosa* Takayanagi and Saito. BLOW, 1969, Proc. First International Conference on Planktonic Microfossils, vol. 1, pp. 345-346, pl. 33 and pl. 34.

"Test low trochospiral, biconvex, but occasionally almost flat in spiral side, equatorial periphery lobate axial periphery rounded; chambers ovate, 10 to 14 arranged in about two whorls, usually six to seven in last whorl, chambers increasing in size in last whorl somewhat irregular, frequently last and/or penultimate chambers much reduced in size compared with preceding ones in last whorl; last chamber occasionally somewhat protruding and tending to be displaced towards umbilical side; sutures not limbate, radial to slightly curved, depressed on spiral side, radial to faintly curved, depressed on umbilical side; wall calcareous, thick, cancellate, surface granular in appearance; umbilicus fairly wide and-deep,

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PLATE 46
JACKSON BLUFF FORMATION ?
CANCELLARIA FAUNIZONE ?
R. L. GAINER FARM

Figures Page

1. *Globorotalia (Globorotalia) multicamerata* Cushman and Jarvis. . . . . 104
Maximum diameter, 0.57 mm
   a. Spiral view, X 87
   b. Edge view, X 85
   c. Umbilical view, X 86

2. *Globorotalia (Globorotalia) cultrata* subsp. . . . . 26
Maximum diameter, 0.27 mm
   a. Spiral view, X 182
   b. Edge view, X 180
   c. Umbilical view, X 181

3. *Hastigerina (Hastigerina) siphonifera siphonifera* (d'Orbigny). . . . . 124
Maximum diameter, 0.51 mm
   a. Spiral view, X 99
   b. Edge view, X 99
   c. Umbilical view, X 99

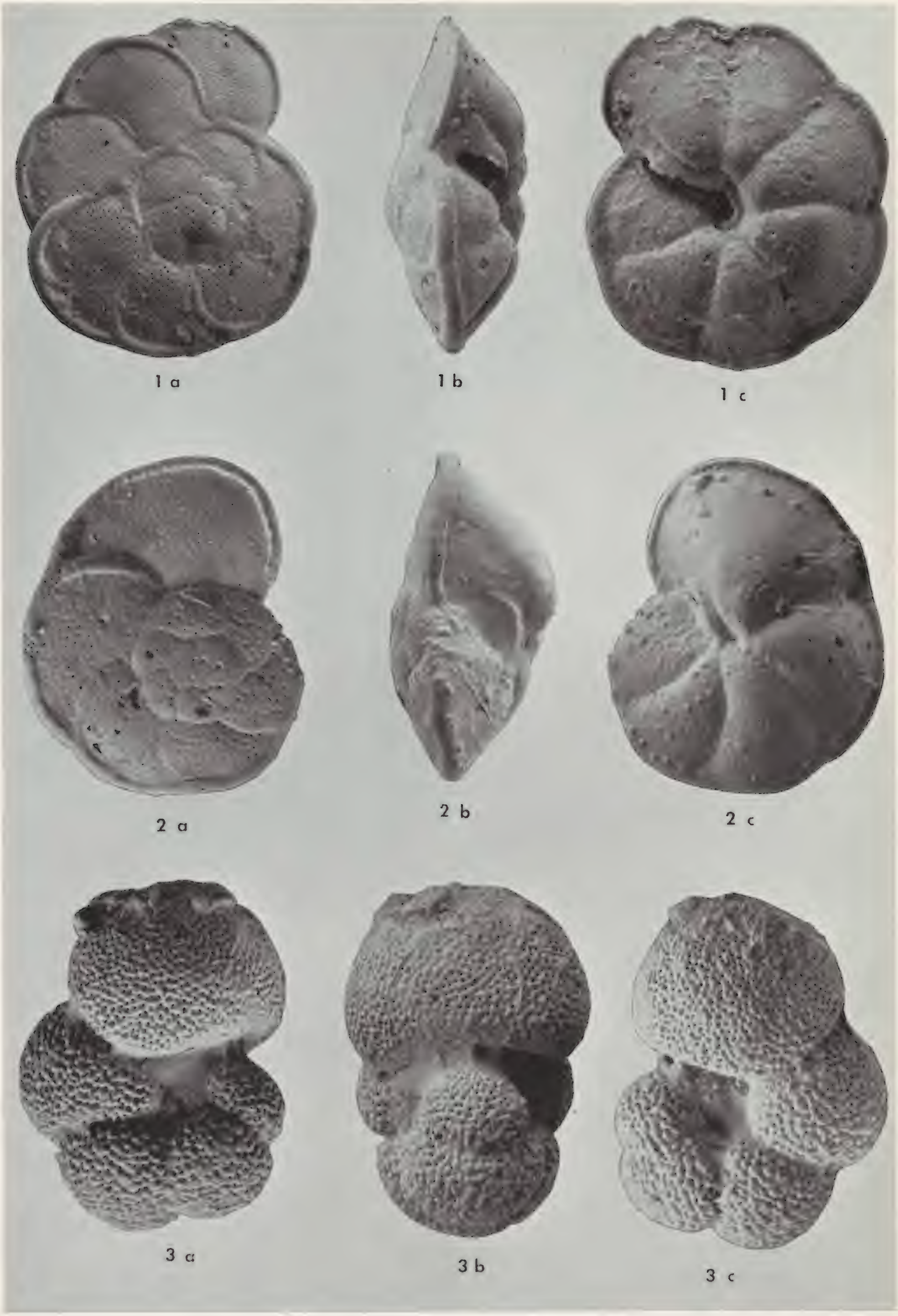


Plate 46

aperture medium to low arch, with a narrow distinct lip, interiomarginal, umbilical-extraumbilical, apertural openings of preceding chambers often connected with last one to make large channeled hollow; coiling of tests is mostly in right direction. Maximum diameter of holotype, 0.46 mm. maximum thickness, 0.32 mm. Maximum diameter of paratype, 0.44 mm, maximum thickness, 0.31 mm." (Takayanagi and Saito, 1962)

Holotype: IGPS 75079; Nobori Formation, Shikoku, Japan.

*Discussion:* The range, according to Blow, is from Zone N. 16 to Zone N. 23. If Parker and the writer are correct in the derivation of *Globoquadrina dutertrei* (d'Orbigny) from this form, one must question the generic affinities involved. There are differences of opinion on this subject, and the choice made here is purely an arbitrary one. Specimens are recorded at Blount's Creek, Jackson Bluff, Watson's Landing, Darling Slide, Gainer Farm, TU 875 (Waccamaw Formation), and in the Yorktown Formation at TU 613 and TU 1022.

## GLOBOROTALIA (TURBOROTALIA) ACOSTAENSIS PSEUDOPIMA Blow

*Globorotalia (Turborotalia) acostaensis pseudopima* BLOW, 1969, Proc. First International Conference on Planktonic Microfossils, vol. 1, pp. 387-388, pl. 35, figs. 1-7.

"The large test consists of 10 chambers arranged in a low trochospire with 4 1/2 inflated, subspherical chambers in the final whorl (only 4 chambers visible ventrally). The chambers are closely appressed; the ventral intercameral sutures are not deeply incised but are shallow. The umbilicus is small, almost closed and the ventral shoulder of the final chamber overhangs the umbilicus. The aperture is interiomarginal, umbilical-extraumbilical and extends slightly beyond the mid-plane of the periphery and thus encroaches slightly onto the dorsal side. The aperture is a low arch and is bordered by a thickened rim-like lip which is "tucked" under the inflated apertural face of the final chamber. The spire is strongly depressed and does not protrude above the plane of the dorsal surfaces of the last whorl of chambers. The ventral intercameral sutures are sub-radial and the dorsal spiral suture is indistinct. The wall is calcareous, radial hyaline, moderately densely perforate and the pores open into comparatively small but deep pits. The early parts of the test tend to be rather rugose but the final chamber is relatively smooth without distinct hispidity. Maximum diameter of holotype, 0.56 mm." (Blow, 1969)

Holotype: British Petroleum Collections; from the Otim River Section, Sarmi Formation, West Irian, Zone N. 21.

*Discussion:* Very rare but typical specimens occur in the Waccamaw Formation at both TU 870 and TU 875 (see discussion under Waccamaw Formation). The form is said to range from the base of Zone N. 20 to Zone N. 23.

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## PLATE 47
## YORKTOWN FORMATION
## RICE'S PIT

Figures Page

1. *Globigerina bulloides bulloides* d'Orbigny. . . . . 48
Maximum diameter, 0.50 mm
a. Spiral view, X 112
b. Umbilical view, X 112

2. *Globigerina bulloides bulloides* d'Orbigny. . . . . 48
Maximum diameter, 0.41 mm
a. Spiral view, X 115
b. Umbilical view, X 114

3. *Globigerina bulloides apertura* Cushman. . . . . 46
Maximum diameter, 0.47 mm
a. Spiral view, X 148
b. Umbilical view, X 148

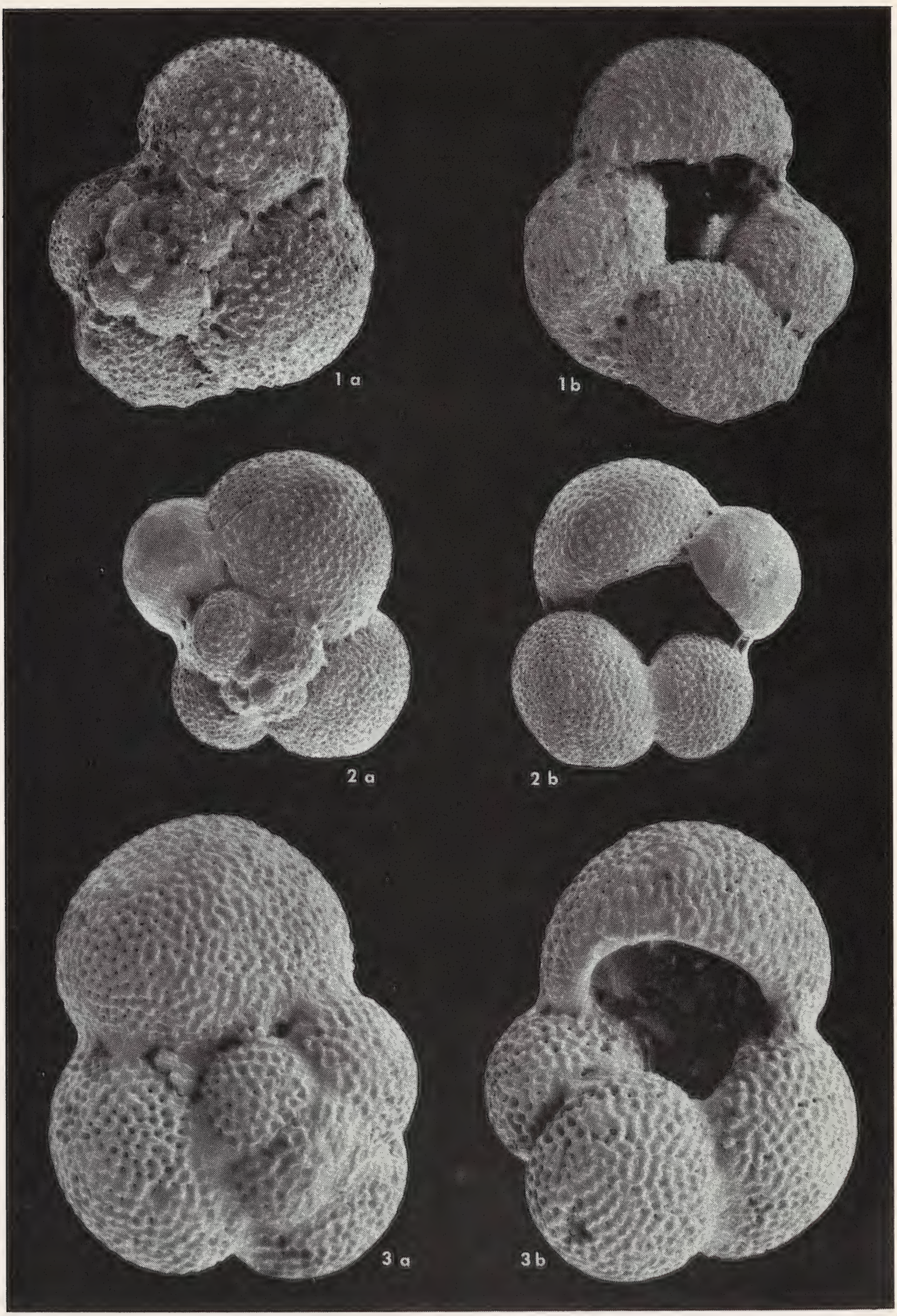


Plate 47

## GLOBOROTALIA (TURBOROTALIA) INFLATA (d'Orbigny)

Pl. 52, fig. 3; Pl. 57, fig. 2

*Globigerina inflata* D'ORBIGNY *in* BARKER-WEBB and BERTHELOT, 1839, Hist. Nat. Îles Canaries, "Foraminifères," vol. 2, pt. 2, p. 134, pl. 2, figs. 7-9.

*Globorotalia (Turborotalia) inflata* (d'Orbigny). BANNER and BLOW, 1967, Micropaleontology, vol. 13, no. 2 pp. 144-146, pl. 4, figs. 1a-c (neotype), 11.

*Globorotalia (Turborotalia) inflata* (d'Orbigny). BLOW, 1969, Proc. First International Conference on Planktonic Microfossils, vol. 1, p. 350, pl. 10, figs. 10-12.

"The test of the neotype consists of approximately three whorls of chambers coiled in a low trochospire. The early whorls have five chambers in each whorl, but the last whorl possesses four chambers only. The test is almost wholly involute ventrally and almost wholly evolute dorsally. The chambers are slightly inflated dorsally, relatively strongly inflated ventrally, and subovoid in axial view, the axial profile being distinctly more convex ventrally than dorsally. The dorso-ventral periphery is broadly rounded in axial view and weakly lobulate in equatorial view. Dorsally, the initial sutures are indistinct (except when the test is clarified by liquids), but they become increasingly (although still shallowly) depressed at successive ontogenetic stages. The dorsal intercameral sutures are curved and meet the spiral suture at broad angles. The early chambers, in dorsal view, are reniform in outline, but they become increasingly longer than broad during ontogeny. The later chambers also acquire greater breadth at their posterior than at their anterior ends. The last-formed chamber slightly embraces the outer part of the dorsal surface of the penultimate whorl. Ventrally, the intercameral sutures are distinctly but not strongly depressed, and are subradial. They meet the periphery and the umbilicus at broad angles approaching right angles. The umbilicus is narrow but open and deep; it is sharply delimited by the umbilical shoulders of the first three chambers of the last whorl and by the inner part of the apertural face of the last chamber. The aperture is a broad, high arch, interiomarginal, ventral and intraumbilical-extraumbilical in position, extending along the basal suture of the narrow, convex apertural face almost as far as its junction with he periphery of the penultimate whorl. The aperture possesses no distinct lip, but the apertural face is thickened, hyaline and granular above the aperture throughout its length. The walls of the test are uniformly perforate, but the perforations are superficially obscured in the early chambers by surface granularity, both dorsally and ventrally. The granularity is most marked, dorsally, on the surface of the early whorls, and ventrally, in the area immediately around the umbilicus and immediately facing the aperture. The wall of the last-formed chamber is smooth, except on the apertural face. Maximum diameter: 0.52 mm, maximum thickness: 0.33 mm." (Banner and Blow, 1967)

Neotype: British Museum (Natural History) 1966.2.3.23; from a sample dredged by H.M.S. *Challenger* at Stn. 8, off Gomera, Canary Islands (28° 3' 15" N. lat., 7° 27' 00" W. long.) in 378 meters of water. D'Orbigny's specimens were from the Holocene sands off Santa Cruz, Teneriffe, Canary Islands.

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## PLATE 48
## YORKTOWN FORMATION
## RICE'S PIT

Figures Page

1. *Globorotalia (Turborotalia) acostaensis humerosa* Takayanagi and Saito. . . . . 108
Maximum diameter, 0.53 mm

a. Spiral view, X 112
b. Umbilical view, X 112
c. Edge view, X 112

2. *Globigerinoides bollii* Blow. . . . . .54
Maximum diameter, 0.31 mm

a. Spiral view, X 175
b. Umbilical view, X 175

3. *Globigerinoides obliquus extremus* Bolli and Bermúdez. . . . . .58
Maximum diameter, 0.38 mm

a. Spiral view, X 161
b. Umbilical view, X 161

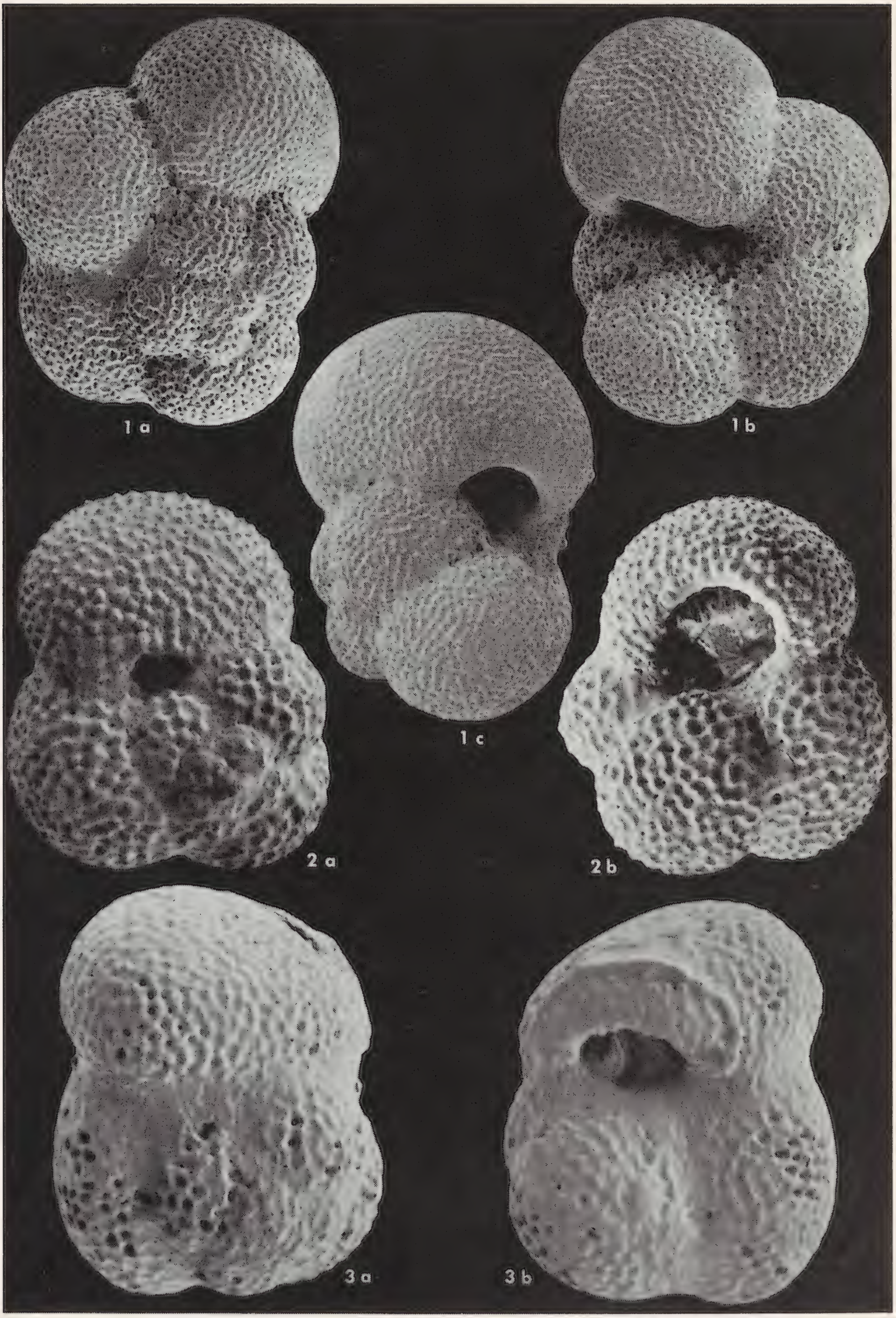


Plate 48

*Discussion:* The range of this form is from within Zone N. 17 to Zone N. 23, according to Blow. Specimens were identified in the Waccamaw Formation at TU 870 and TU 875.

## GLOBOROTALIA (TURBOROTALIA) MINIMA Akers

Pl. 13, fig. 2

*Globorotalia canariensis* (d'Orbigny) var. *minima* AKERS, 1955, Jour. Paleontology, vol. 29, no. 4, p. 659, pl. 65, figs. 3a-d.

*Globorotalia minima* Akers. BLOW, 1959, Bull. Amer. Paleontology, vol. 39, no. 178, p. 217, pl. 19, figs. 122a-c.

"Test low trochospiral; spire opening rapidly, with usually six chambers in the last convolution. As seen from the spiral side the chambers are almost equally as broad as long with the exception of the last two chambers. The sutures of the spiral side are not much depressed and are moderately curved. The sutures of the umbilical side are slightly sinuous to almost radial. Equatorial periphery only slightly lobate; axial periphery rounded to subacute, not keeled; aperture interiomarginal, umbilical-extraumbilical, a low arch with a thin short lip; umbilicus small or closed; wall calcareous, finely perforate." (Blow, 1959)

Holotype: USNM P4754; from core 10,132-10,142 feet, Humble Ellender No. 1 Well, Lirette Field, Terrebonne Parish, Louisiana. The height is 0.22 mm; width, 0.20 mm; thickness, 0.11 mm.

*Discussion:* There is confusion in the literature regarding the stratigraphy of this Louisiana well (Ellisor, 1940) and the actual source of foraminifera described from it by Cushman and Ellisor (1939). On the basis of these earlier published data, Akers (1955) believed that this form was derived from an older zone than is now known to have been penetrated by the well. Additional drilling with detailed paleontological and electrical log correlations have established that the Humble Ellender No. 1 penetrated beds no older than the *Bigenerina nodosaria directa-Cibicides carstensi* Zone (see Butler, 1962). This interval is correlative with Zone N. 14 and represents the highest occurrence of *Globorotalia minima,* rather than Zone N. 13, as Blow (1969) was led to believe. Blow reports the lowest occurrence of this species within Zone N. 7, although the writer has not seen it in beds that old.

Between 100 and 200 specimens were observed in the core from which the form was described, and all are of the same approximate dimensions of the holotype. Coiling throughout the range in the Ellender well (14 cores between 9,592 and 11,304 feet) was not less than 90% sinistral in any sample. Blow (1959, p. 217) reported that his specimens from the Pozón-El Mene Road section, eastern Falcón,

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## PLATE 49
## YORKTOWN FORMATION
## RICE'S PIT

Figures Page

1. *Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny). . . . . 62
Maximum diameter, 0.63 mm
a. Spiral view, X 94
b. Umbilical view, X 94

2. *Globigerinoides ruber* (d'Orbigny). . . . . 66
Maximum diameter, 0.51 mm
a. Spiral view, X 110
b. Umbilical view, X 110

3. *Sphaeroidinellopsis subdehiscens subdehiscens* Blow. . . . . 86
Maximum diameter, 0.37 mm
a. Spiral view, X 162
b. Umbilical view, X 162

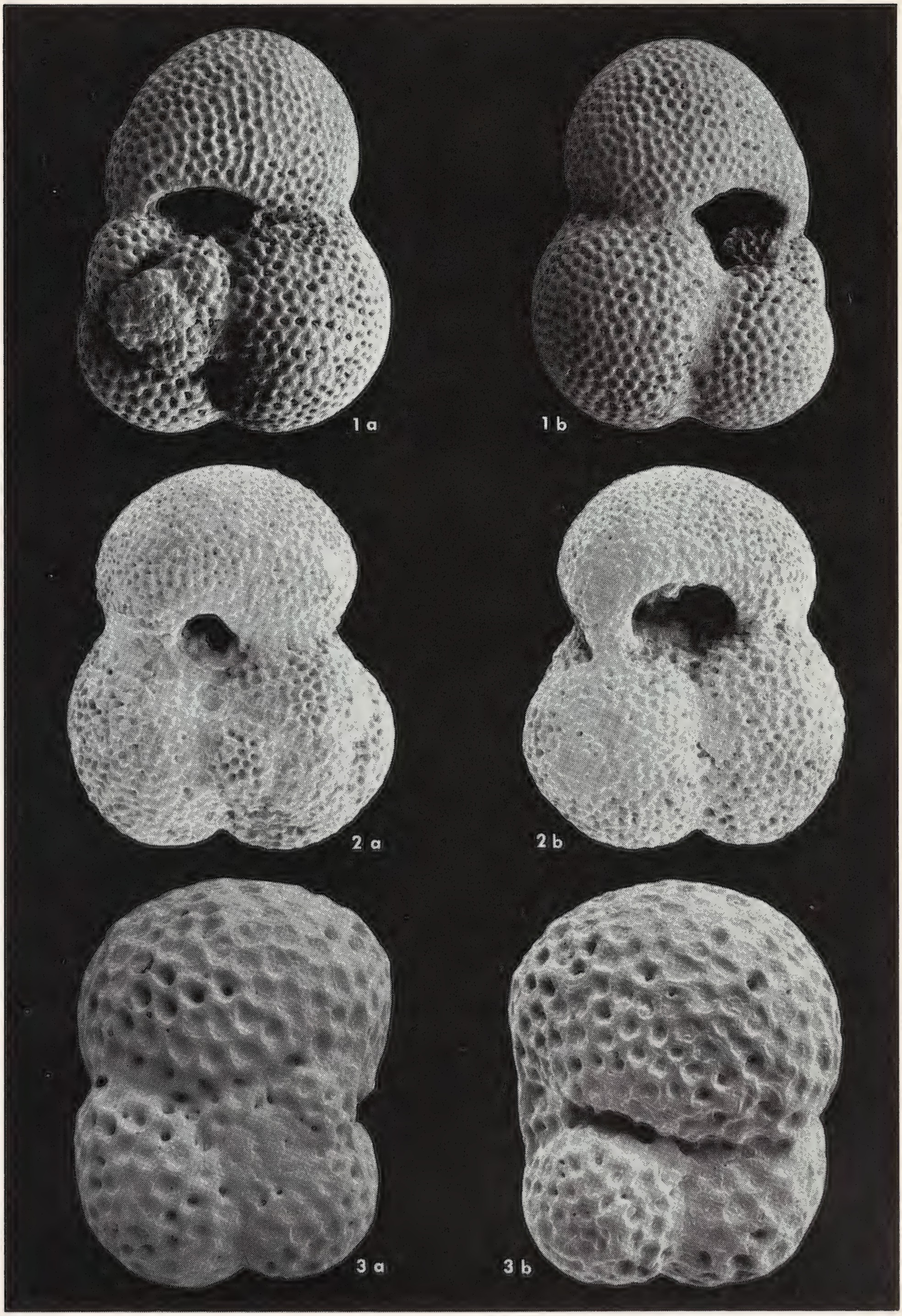


Plate 49

Venezuela, were of the same average dimensions as the Louisiana specimens.

Five specimens were found at the Cosson Farm site, Yellow River Formation. All are sinistrally coiled, and all are close to the dimensions of the holotype. All also compare closely in morphologic detail with the Louisiana specimens, although this is not evident in the scanning electron photomicrographs, because of the translucent character of the test. A comparison of actual specimens from the Yellow River Formation with topotypes is convincing that they are conspecific.

## GLOBOROTALIA (TURBOROTALIA) OBESA Bolli

Pl. 3, fig. 1

*Globorotalia obesa* BOLLI, 1957, U. S. Natl. Mus., Bull. 215, p. 119, pl. 29, figs. 2a-3.
*Globorotalia obesa* Bolli. BLOW, 1959, Bull. Amer. Paleontology, vol. 39, no. 178, p. 218, pl. 19, figs. 124a-c.

"Shape of test very low trochospiral; equatorial periphery strongly lobate; axial periphery rounded. Wall calcareous, perforate, surface finely pitted, in well-preserved specimens with fine, short spines. Chambers strongly inflated, spherical; ten to twelve, arranged in two to two and one-half whorls; the four to four and one-half chambers of the last whorl increase rapidly in size. Sutures on spiral side radial, strongly depressed; on umbilical side radial, strongly depressed. Umbilicus fairly wide, deep. Aperture a medium to high arch without lip or rim; interiomarginal, umbilical-extraumbilical. Coiling random. Largest diameter of holotype, 0.5 mm." (Bolli, 1957)

Holotype: USNM P5673; Cipero Formation, about 1/6 mile south of Golconda Village, southern Trinidad.

*Discussion:* In the Cipero Formation, specimens are common in which the final chamber extends over and on to the spiral side, the aperture becoming nearly interiomarginal and peripheral. Blow described this as a gerontic feature of specimens in the Pozón Formation of Venezuela. He considers the species long-ranging (Zone N. 2 to Zone N. 23) and ubiquitous (Blow, 1969, p. 352). Parker (1967, p. 152) considers this species as the "direct forerunner" of *Globigerinella siphonifera* (d'Orbigny).

## GLOBOROTALIA (TURBOROTALIA) PRAEOSCITANS Akers, new species

Pl. 32, fig. 3; Pl. 36, fig. 3;
Pl. 50, fig. 2; Pl. 51, fig. 3

Test moderately large, planoconvex, sinistrally coiled with 10 to 13 chambers comprising the spire and four to five chambers in the final whorl. The equatorial profile is slightly lobulate. In axial profile, the test appears cuneiform because of the abrupt inflation, both lateral and vertical, of the final chamber in contrast with the periphery of the antepenultimate chamber. Sutures are distinct and slightly recurved. The wall is finely perforate with a foraminal density which is consistent for all specimens seen. Pustules may occur on both sides of the test, but in some specimens they may be confined to

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PLATE 50
YORKTOWN FORMATION
RICE'S PIT

Figures Page

1. *Hastigerina (Hastigerina) siphonifera siphonifera* (d'Orbigny). . . . . 124
Maximum diameter, 0.43 mm

a. Spiral view, X 150
b. Edge view, X 148
c. Umbilical view, X 147

2. *Globorotalia (Turborotalia) praeoscitans* Akers, new species . . . . . 116

USNM 180583, holotype. Maximum diameter, 0.47 mm

a. Edge view, X 148
b. Spiral view, X 139
c. Umbilical view, X 148

Plate 50

the central region of the umbilical side. The aperture is a large interiomarginal, umbilical-extraumbilical, semi-circular opening with a narrow lip, which is smooth in some specimens but pustulate in others.

Holotype: USNM 180583; pl. 50, fig. 2; Yorktown Formation at Rice's Pit (TU 613); maximum diameter 0.47 mm.

Paratypes: (1) USNM 180584; pl. 32, fig. 3; Jackson Bluff Formation at Darling Slide (TU 712); maximum diameter 0.30 mm. (2) USNM 180585; pl. 36, fig. 3; Jackson Bluff Formation at Jackson Bluff, Bed 9; maximum diameter 0.31 mm. (3) USNM 180586; pl. 51, fig. 3; Yorktown Formation at Rice's Pit (TU 613); maximum diameter 0.42 mm.

*Discussion: Globorotalia (T.) praeoscitans,* new species, *Globorotalia (T.) oscitans* Todd, *Globorotalia (T.) bononiensis* Dondi, and *Globorotalia (T.) inflata* (d'Orbigny) appear to be an interrelated complex characterized by abrupt and extreme cameral inflation and a very large, arcuate to semicircular aperture which, except in *Globorotalia (T.) inflata,* is demarcated by a narrow lip. *Globorotalia (T.) praeoscitans* is almost twice the diameter of *Globorotalia (T.) oscitans,* has a larger aperture, and is more cuneiform in axial profile. *Globorotalia (T.) bononiensis* is approximately the same size as *Globorotalia (T.) praeoscitans,* and it also has a large aperture, but Dondi's species appears to be biconvex, and the cameral inflation is more gradual. This is also true of *Globorotalia (T.) inflata,* which has the most globose chambers of the complex.

*Globorotalia (T.) praeoscitans* has been seen also at the Darling Slide locality, Jackson Bluff, Bed 9 (Jackson Bluff Formation, *Ecphora* Faunizone), and in the Yorktown Formation at Wilson's Pit (TU 613). These beds are considered to be lowermost Pliocene to lower middle Pliocene (later part of Zone N. 18 to the later part of Zone N. 19).

*Globorotalia (T.) praeoscitans* is abundant in Yorktown beds at the Texas Gulf Sulphur Company mine near Aurora, North Carolina (TU 1022). This species and *Globigerina bulloides* are the predominant components of the planktonic assemblage.

### GLOBOROTALIA (TURBOROTALIA) SCITULA SCITULA (Brady)

*Pulvinulina scitula* BRADY, 1882, Roy. Soc. Edinburgh, Proc., vol. 11 (1880-1882), no. 111, pp. 716-717, (no figure); lectotype of Banner and Blow, 1960.

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## PLATE 51
## YORKTOWN FORMATION
## RICE'S PIT

Figures

Page

1. *Globorotalia (Globorotalia)* sp. . . . . 32
Maximum diameter, 0.45 mm
a. Spiral view, X 134
b. Umbilical view, X 136
c. Edge view, X 134

2. *Globorotalia (Globorotalia) cultrata* subsp. . . . . 32
Maximum diameter, 0.58 mm
a. Edge view, X 78
b. Umbilical view, X 80
c. Spiral view, X 79

3. *Globorotalia (Turborotalia) praeoscitans* Akers, new species . . . . . 116
USNM 180586, paratype. Maximum diameter, 0.42 mm
a. Spiral view, X 132
b. Edge view, X 133
c. Umbilical view, X 133

Plate 51

*Pulvinulina patagonica* (d'Orbigny). BRADY, 1884, Rept. Voy. *Challenger,* Zool., vol. 9, pt. 22, p. 693, pl. 103, figs. 7a-c (*non Rotalina patagonica* d'Orbigny 1839).

*Globorotalia scitula* (Brady). CUSHMAN and HENBEST, 1940, U. S. Geol. Surv., Prof. Paper 196-A, pt. 2, p. 36, pl. 8, figs. 5a-c.

*Globorotalia scitula scitula* (Brady). BLOW, 1959, Bull. Amer. Paleontology, vol. 39, no. 178, p. 219, pl. 19, figs. 126a-c.

*Pulvinulina scitula* Brady. BANNER and BLOW, 1960, Cushman Found. Foram. Res., Contr., vol. 11, pp. 27, 29, pl. 5, figs. 5a-c (lectotype designated).

*Globorotalia (Turborotalia) scitula scitula* (Brady). BLOW, 1969, Proc. First International Conference on Planktonic Microfossils, vol. 1, p. 356, pl. 39, fig. 7.

"The fairly small test consists of about 14 chambers arranged in nearly three whorls, which comprise a low trochospire with 5-6 chambers in a whorl. The chambers are slightly embracing and uniformly and slowly enlarging; they are little, if at all, inflated dorsally but are slightly inflated ventrally. The equatorial profile of the test is subcircular and possesses a periphery which becomes increasingly, although still weakly, lobulate in ontogeny. The axial profile shows that the test is compressed dorso-ventrally; the peripheral margin is acutely rounded but it is not carinate or secondarily thickened (i.e., no pseudocarina is present). The sutures are slightly depressed, not limbate or thickened, and the spiral suture is weakly lobulate. The dorsal intercameral sutures are strongly recurved and vorticiform; the distal ends of these sutures are smoothly tangential to the periphery. In the earlier ontogenetic stages the proximal ends of the intercameral dorsal sutures meet the spiral suture at a broadly acute angle, but later in ontogeny these sutures meet the spiral suture almost at right angles. The chambers of the last whorl show a decrease in the amount of embrace dorsally and simultaneously become even less inflated on that side of the test than they were earlier; this is associated with a step-like appearance which develops between successive chambers on the dorsal surface of the last whorl. The ventral sutures are nearly radial; initially they are smoothly curved, but later they become slightly sigmoidal. The umbilicus is small and it is almost closed by an umbilical lobe of the last chamber. The primary aperture is interiomarginal, umbilical-extraumbilical; it is a low arch extending from the umbilicus for about three quarters of the length of the terminal basal suture. The aperture possesses a uniformly very narrow and thin lip. The apertural face is slightly concave in its distal region but is smoothly convex near the umbilicus; it is not clearly delimited from the ventral surface of the last chamber. The wall of the test is thin and is uniformly and very finely perforate except for a weakly

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## PLATE 52
## WACCAMAW FORMATION
## TU 875

Figures Page

1. *Globigerinita uvula* (Ehrenberg). . . . . 72
   Maximum diameter, 0.30 mm
   a. Spiral view, X 181
   b. Umbilical view, X 182

2. *Globigerina juvenilis* Bolli. . . . . 52
   Maximum diameter, 0.33 mm
   a. Spiral view, X 154
   b. Umbilical view, X 154

3. *Globorotalia (Turborotalia) inflata* (d'Orbigny), a juvenile specimen. . . . . 112
   Maximum diameter, 0.31 mm
   a. Spiral view, X 161
   b. Umbilical view, X 161

4. *Globigerina bulloides bulloides* d'Orbigny. . . . . 48
   Maximum diameter, 0.46 mm
   a. Umbilical view, X 136
   b. Spiral view, X 138

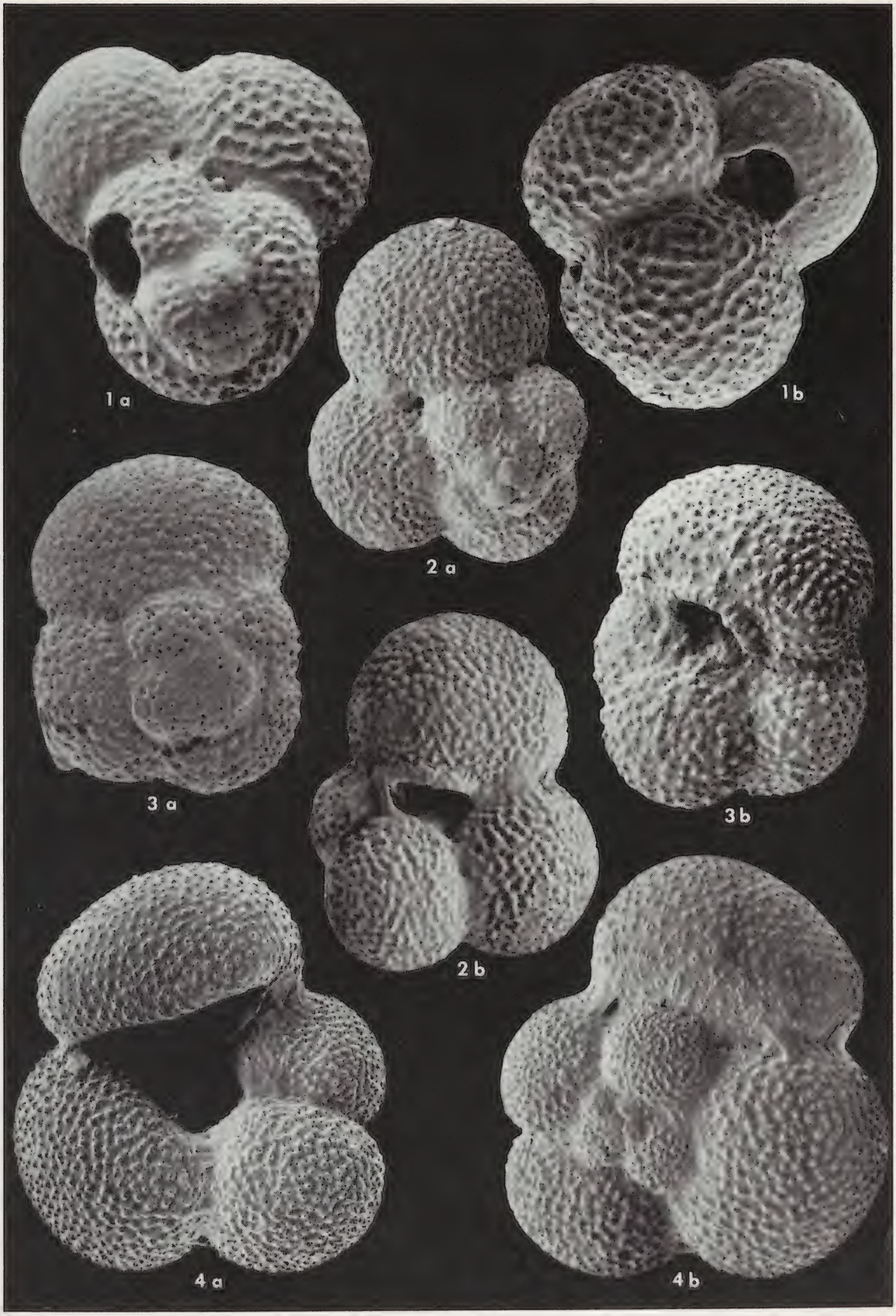


Plate 52

pustulose area on the ventral surface of the first chamber of the last whorl (facing the terminal aperture). The surface of the test is fairly smooth and shows little trace of any original hispidity; it possesses a characteristic glistening and a somewhat translucent appearance. Maximum diameter of lectotype: 0.31 mm." (Banner and Blow, 1960)

Lectotype: British Museum (Natural History) 1959.6.25.1; from the Faroe Channel at a depth of 7530 fathoms.

*Discussion:* The range of this form is from within the later parts of Zone N. 9 to Zone N. 23 (Blow, 1969). Specimens were identified at Watson's Landing.

### GLOBOROTALIA (TURBOROTALIA) SIAKENSIS (LeRoy)

Pl. 5, fig. 1; Pl. 13, fig. 3

*Globigerina siakensis* LEROY, 1939, Natuurk. Tijdschr. Nederl.-Indie, vol. 99, no. 6, pp. 39-40, pl. 3, figs. 30-31.

*Globorotalia mayeri* Cushman and Ellisor. BOLLI, 1957, U. S. Natl. Mus., Bull. 215, p. 118, pl. 28, figs. 4a-c.

*Globorotalia mayeri* Cushman and Ellisor. BLOW, 1959, Bull. Amer. Paleontology, vol. 39, no. 178, p. 214, pl. 18, figs. 116a-c.

*Globorotalia (Turborotalia) siakensis* (LeRoy). BLOW, 1969, Proc. First International Conference on Planktonic Microfossils, vol. 1, p. 356, pl. 10, figs. 7-9 (holotype refigured); pl. 34, figs. 4, 5.

Blow (1969) clarifies this form as follows: "*Globorotalia (T.) siakensis* has frequently been misidentified as *mayeri*. *G. (T.) siakensis* appears to be ubiquitous in equatorial, tropical and subtropical assemblages. Characteristically, the species possesses virtually radial intercameral sutures both dorsally and ventrally and a distinctly open, but deep, umbilicus. The aperture is a fairly low, elongated arched opening and the apertural lip is not particularly well developed although usually present and distinct. The chambers of the last whorl are subglobular, moderately inflated and not greatly appressed or embracing. Normally 5-6 chambers are present in the final whorl but 7-8 chambers have been observed, rarely, in the final convolution of the test." (Blow, 1969)

Holotype: Geological Museum, Bandung, Indonesia, P.S. 1075a; Miocene ?, Central Sumatra.

*Discussion:* Range is from the latest part of Zone N. 2 to the top of Zone N. 14, according to Blow. This species was identified in the Chipola Formation and at the Cosson Farm locality (Yellow River Formation).

### Genus TURBOROTALITA Blow and Banner, 1962

### TURBOROTALITA QUINQUELOBA (Natland)

Pl. 41, fig. 1; Pl. 45, fig. 1

*Globigerina quinqueloba* NATLAND, 1938, Univ. Calif., Scripps Inst. Oceanography, Bull., Tech. Ser., vol. 4, no. 5, p. 149, pl. 6, fig. 7.

*Globigerina groenlandica* STSCHEDRINA, 1946, Artich. Nauch. Issl. Inst. Dreif. Eksped. Glavs.

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## PLATE 53
## WACCAMAW FORMATION
## TU 875

Figures Page

1. *Globigerinoides ruber* (d'Orbigny). . . . . 66
   Maximum diameter, 0.48 mm
   a. Spiral view, X 136
   b. Umbilical view, X 137

2. *Globigerinoides obliquus obliquus* Bolli. . . . . 60
   Maximum diameter, 0.39 mm
   a. Spiral view, X 141
   b. Umbilical view, X 141

3. *Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny). . . . . 62
   Maximum diameter, 0.54 mm
   a. Spiral view, X 122
   b. Umbilical view, X 122

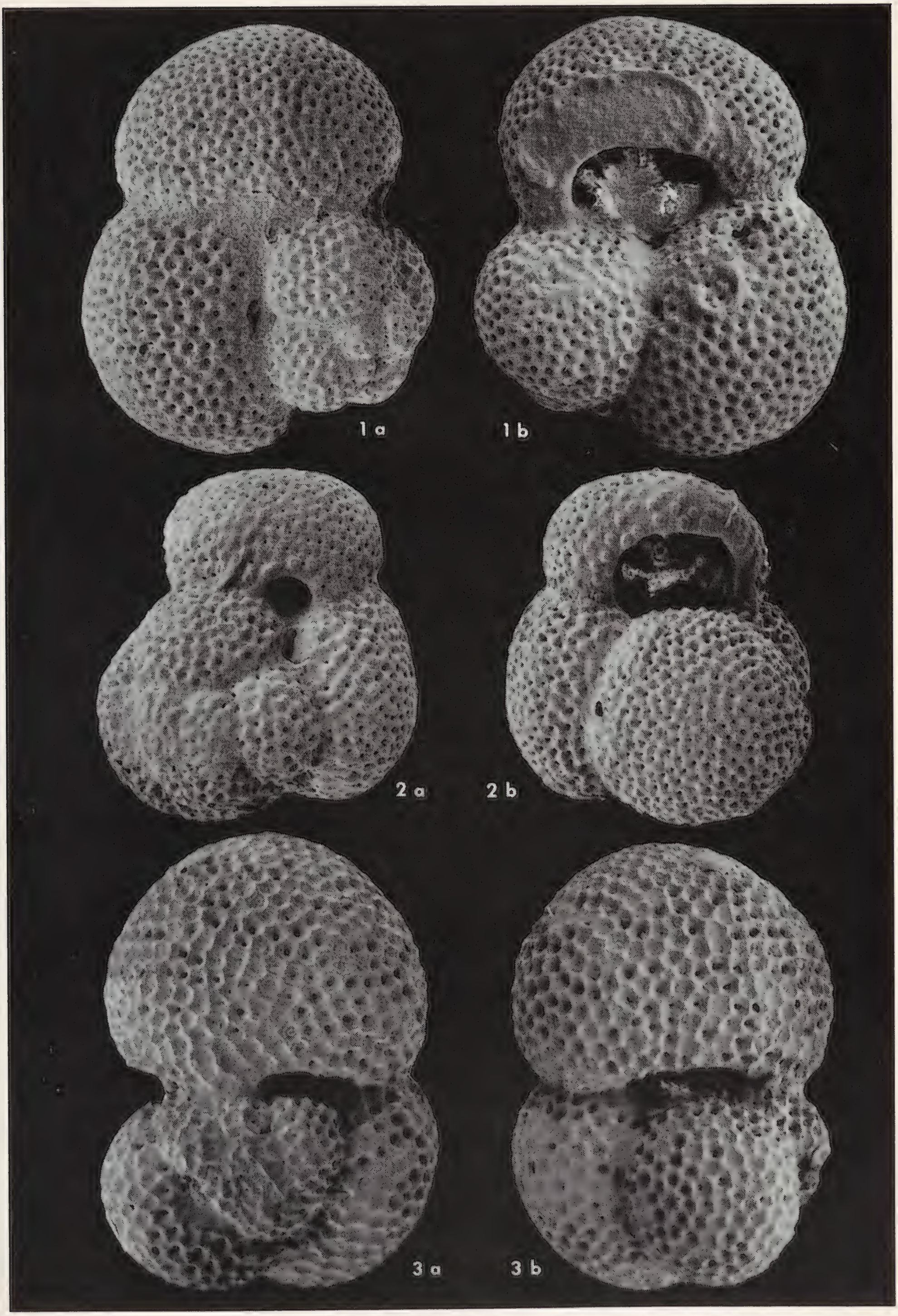


Plate 53

Ledok. Parokh. "G. Sedov" 1937-1940, Trudy, vol. 3 (Biology), p. 145, pl. 4, fig. 23.

"Test small, trochoid, roughly trapezoidal in side view, last convolution made up of five chambers rather rapidly increasing in size as added; chambers inflated, subspherical; walls roughened; sutures depressed; aperture an elongated slit with overhanging lip almost covering the umbilicus. Length, 0.24 mm, breadth 0.22 mm, thickness, 0.14 mm." (Natland, 1938)

Holotype: USNM 22559; off Long Beach, California, in 152 meters of water.

*Discussion:* The range of this taxon is from within the earlier parts of Zone N. 17 to Zone N. 23 (Blow, 1969). The species is abundant at Watson's Landing, but the specimens are only three quarters the size of the holotype. Otherwise, specimens are typical.

## Genus GLOBOROTALOIDES Bolli, 1957

### GLOBOROTALOIDES HEXAGONA HEXAGONA (Natland)

Pl. 28, fig. 1

*Globigerina hexagona* NATLAND, 1938, Univ. Calif., Scripps Inst. Oceanography, Bull., Tech. Ser., vol. 4, no. 5, p. 149, pl. 7, fig. 1.

*Globoquadrina hexagona* (Natland). PARKER, 1962, Micropaleontology, vol. 8, no. 2, p. 244, pl. 8, figs. 5-13.

*Globoquadrina hexagona* (Natland). PARKER, 1967, Bull. Amer. Paleontology, vol. 52, no. 235, p. 169, pl. 25, figs. 9, 10.

*Globorotaloides hexagona hexagona* (Natland). BLOW, 1969, Proc. First International Conference on Planktonic Microfossils, vol. 1, pp. 373-374.

"Test medium sized, trochoid, low spired; chambers spherical, rapidly increasing in size as added, five in each whorl; sutures depressed, radiate; walls with coarse reticulations forming hexagonal pits which give the walls a honeycombed appearance; aperture a slightly arculate opening between the umbilicus and the periphery at the base of the last chamber. Length, 0.39 mm; breadth, 0.33 mm; thickness 0.18 mm." (Natland, 1938)

Holotype: USNM 496185; from Recent sediments in 884 meters of water, off Long Beach, California, Lat. 33° 27' 20" N., Long. 118° 19' 00" W.

*Discussion:* Specimens from the Darling Slide locality are identical with the specimens of Natland and Parker. Blow records a range from within Zone N. 18 to Zone N. 23. The form has been noted as locally extinct, however, above Zone N. 21 in the Atlantic-Caribbean-Gulf of Mexico Province. Absence of the subspecies here has been attributed to the possibility that the Atlantic ocean was affected more than the Indian and Pacific oceans by deterioration of late Pliocene and early Pleistocene climate.

## Subfamily HASTIGERININAE Banner and Blow, 1960

## Genus HASTIGERINA Thomson, 1876

### HASTIGERINA SIPHONIFERA SIPHONIFERA (d'Orbigny)

Pl. 9, fig. 1; Pl. 12, fig. 2;
Pl. 17, fig. 3; Pl. 24, fig. 3;
Pl. 26, fig. 1; Pl. 31, fig. 4;
Pl. 46, fig. 3; Pl. 50, fig. 1;
Pl. 54, fig. 1; Pl. 60, fig. 1

*Globigerina siphonifera* D'ORBIGNY *in* DE LA SAGRA, 1839, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 83, pl. 4, figs. 15-18.

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## PLATE 54
## WACCAMAW FORMATION
## TU 875

Figures Page

1. *Hastigerina (Hastigerina) siphonifera siphonifera* (d'Orbigny). . . . . 124
   Maximum diameter, 0.60 mm
   a. Spiral view, X 112
   b. Umbilical view, X 112

2. *Globorotalia (Turborotalia) acostaensis humerosa* Takayanagi and Saito. . . . . 108
   Maximum diameter, 0.43 mm
   a. Spiral view, X 154
   b. Umbilical view, X 154

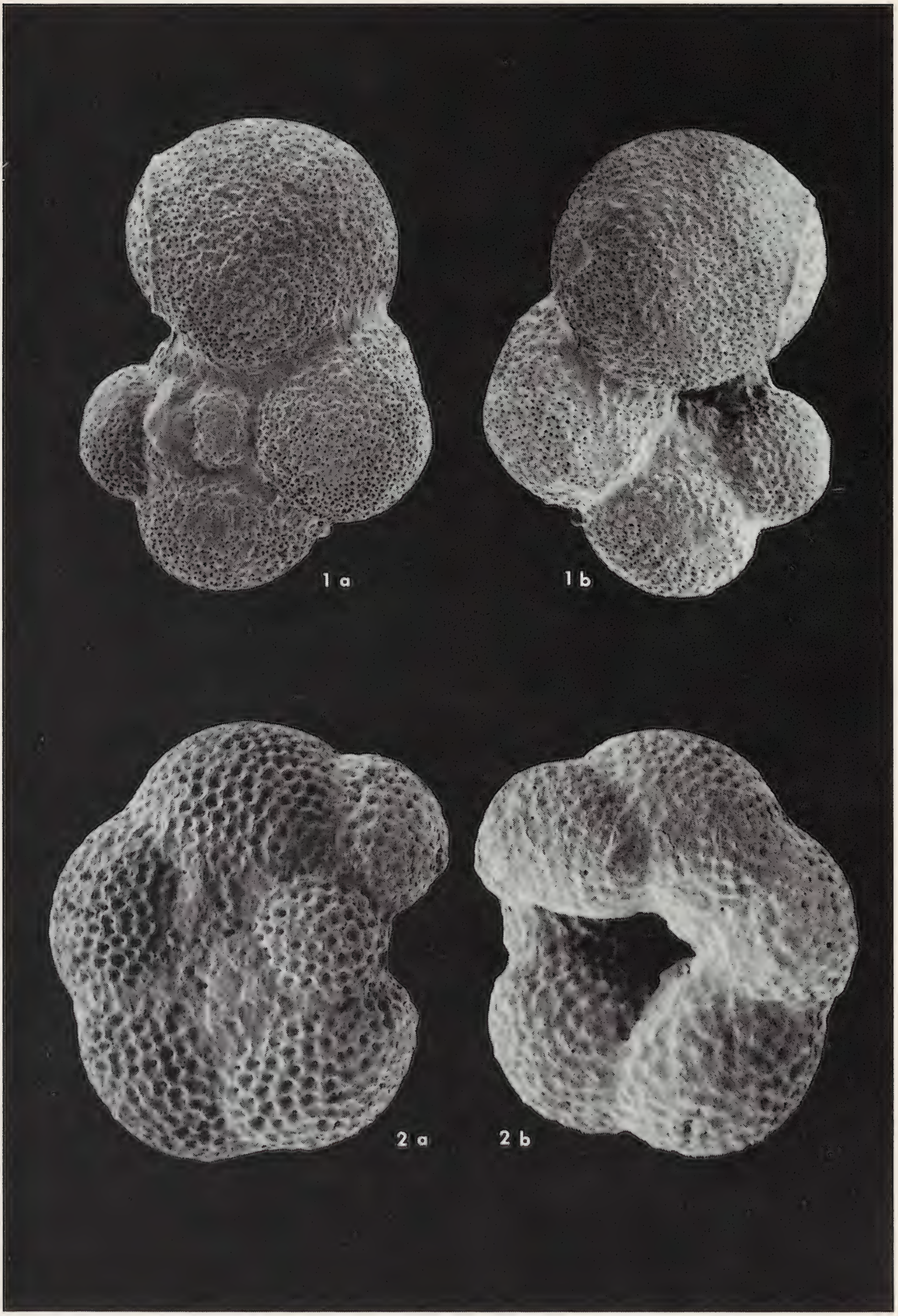


Plate 54

*Globigerina aequilateralis* BRADY, 1879, Quart. Jour. Micro. Sci., (new ser.), vol. 19, p. 285.
*Globigerina aequilateralis* Brady. BRADY, 1884, Rept. Voy. *Challenger,* Zool., vol. 9, p. 605, pl. 80, figs. 18-21.
*Globigerina aequilateralis* Brady var. *involuta* CUSHMAN, 1917, U. S. Natl. Mus., Proc., vol. 51, no. 2172, p. 662.
*Globigerina aequilateralis* Brady var. *involuta* Cushman. CUSHMAN, 1921, U. S. Natl. Mus., Bull. 100, p. 293, text-fig. 11.
*Hastigerina (Hastigerina) siphonifera* (d'Orbigny). BANNER and BLOW, 1960, Micropaleontology, vol. 6, no. 1, p. 22, text-figs. 2 (lectotype), 3.
*Globigerinella siphonifera* (d'Orbigny). PARKER, 1967, Bull. Amer. Paleontology, vol. 52, no. 235, pp. 152-153, pl. 22, fig. 5.
*Hastigerina (H.) siphonifera siphonifera* (d'Orbigny). BLOW, 1969, Proc. First International Conference on Planktonic Microfossils, vol. 1, p. 375.

"D'Orbigny (1839) in his original description, significantly stated that the spire was planar, and the aperture elongate. The "pointes tubuleuse" seem to refer to the characteristic hispidity and numerous spine bases of the species. In the specimen we designate as lectotype, the coiling is virtually planispiral but one side is slightly more involute than the other and there is also an indication that there is a definite earlier trochospiral stage. D'Orbigny's original specimen (according to his writing) was 1/3 of a mm in diameter; the lectotype is 0.46 mm maximum diameter and probably represents a more perfectly planispiral and later growth stage than that of d'Orbigny's original illustrated specimen. The primary aperture of the lectotype is a low equatorial, interiomarginal arch and extends into the ventral and dorsal umbilici. The aperture is bordered by a thin symmetrical, perforate lip of constant breadth. Relict apertures are present in the umbilical margins of the penultimate chamber." (Banner and Blow, 1960)

Lectotype: d'Orbigny Collection, Museum National de l'Histoire Naturelle, Paris; from Cuba, probably from Recent beach sands.

*Discussion:* This form ranges from within Zone N. 12 to Zone N. 23, according to Blow. Specimens were found in all formations investigated, which are younger than the Chipola.

## Genus PULLENIATINA Cushman, 1927

### PULLENIATINA OBLIQUILOCULATA OBLIQUILOCULATA (Parker and Jones)

Pl. 60, fig. 3

*Pullenia obliquiloculata* PARKER and JONES *in* CARPENTER, 1862, Introduction to the Study of the Foraminifera, Roy. Soc., p. 183 *(nomen nudum).*
*Pullenia sphaeroides* (d'Orbigny) var. *obliquiloculata* Parker and Jones. PARKER and JONES, 1865, Roy. Soc. London, Philos. Trans., vol. 155, p. 365, 368, pl. 19, fig. 4.
*Pulleniatina obliqueloculata* [sic] (Parker and Jones). BOLLI, LOEBLICH and TAPPAN, 1957, U. S. Natl. Mus., Bull. 215, p. 33 (lectotype designated), pl. 4, fig. 3a-b (paralectotype).
*Pulleniatina obliquiloculata obliquiloculata* (Parker and Jones, 1865, emended). BANNER and

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## PLATE 55
## WACCAMAW FORMATION
## TU 875

Figures — Page

1. *Globorotalia (Globorotalia) truncatulinoides* (d'Orbigny). . . . . 104
Maximum diameter, 0.45 mm
a. Spiral view, X 136
b. Umbilical view; X 136

2. *Globorotalia (Globorotalia)* sp. . . . . 36
Maximum diameter, 0.35 mm
a. Spiral view, X 143
b. Umbilical view, X 143

3. *Globorotalia (Globorotalia) cultrata menardii* (Parker, Jones and Brady). . . . . 98
Maximum diameter, 0.52 mm
a. Spiral view, X 136
b. Umbilical view, X 136

Plate 55

BLOW, 1967, Micropaleontology, vol. 13, no. 2, pp. 137-139, pl. 3, fig. 4 (lectotype figured), pl. 4, fig. 9.

*Pulleniatina obliqueloculata obliqueloculata* [sic] (Parker and Jones). BLOW, 1969, Proc. First International Conference on Planktonic Microfossils, vol. 1, p. 376.

"The lectotype is a tumid, thick-walled test displaying four and one-half chambers in the last whorl. These chambers appear to be regularly enlarging, and they form a coil which is completely involute ventrally and partially involute dorsally. The first three chambers of the last whorls do not appear to embrace the previous whorl dorsally, but the last-formed two chambers clearly overlap the dorsal surface of the previous whorl. The chambers are globose, and their peripheries are broadly rounded. The walls of the chambers are wholly perforate except for a narrow ventral area facing the aperture. Dorsally, the wall is thicker over the early whorls, where heavy deposition of shell material obscures the shape and disposition of the early chambers. Comparable specimens consist of at least three whorls of chambers in all, with five chambers in the antepenultimate, four in the penultimate, and four and a half in the last. The dorsal exterior surface of the early whorls is smooth and very coarsely perforate, the pores becoming more numerous and of smaller size progressively throughout the last whorl. The pore size and distribution are very similar on both the dorsal and the ventral surfaces of each chamber of the last whorl. The ventral surface is smooth except for a granular area immediately facing the aperture. The dorsal spiral suture and the intercameral sutures of the last whorl are depressed, increasingly so towards the last chamber. The sutures of the early whorls are obscured by shell thickening. The intercameral sutures of the early part of the last whorl are gently recurved, but in the later, more involute part of this whorl they become progressively more radially arranged.

"Ventrally, the chambers completely embrace at their umbilical ends, forming a broad umbilical depression but no true umbilicus. The innermost margin of the last chamber joins the inner ends of the three previous chambers in a continuous, linear, but angular suture. The aperture is a very low, ventral, interiomarginal arch, extending along the base of the very low apertural face from about the periphery of the first chamber of the last whorl almost to the anterior intercameral suture of the second chamber of the last whorl. The aperture possesses no lip, but the inner margin of the apertural face is convex, thickened, hyaline and rim-like throughout the length of the aperture. Scattered small granules occur, especially in the mid-part of the apertural face. The maximum diameter of the test is 0.58 mm, and the maximum thickness is 0.49 mm." (Banner and Blow, 1967)

Lectotype: British Museum, Natural History ZF 3583-ex 94.4.3.1045; from Abrolhos Bank, off the coast of Brazil, 22° 54' S. Lat., 40° 37' W. long., in 260 fathoms.

*Discussion:* This form ranges from within Zone N. 19 to Zone N. 23, according to Blow. Specimens were found in the Moín Formation at TU 954.

## Subfamily CASSIGERINELLINAE Bolli, Loeblich and Tappan, 1957

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## PLATE 56
## WACCAMAW FORMATION
## TU 870

Figures Page

1. *Globigerinoides obliquus obliquus* Bolli. . . . . 60
Maximum diameter, 0.42 mm

a. Spiral view, X 150
b. Umbilical view, X 150

2. *Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny). . . . . 62
Maximum diameter, 0.54 mm

a. Spiral view, X 119
b. Umbilical view, X 118

3. *Globigerinoides ruber* (d'Orbigny). . . . . 66
Maximum diameter, 0.49 mm

a. Spiral view, X 136
b. Umbilical view, X 136

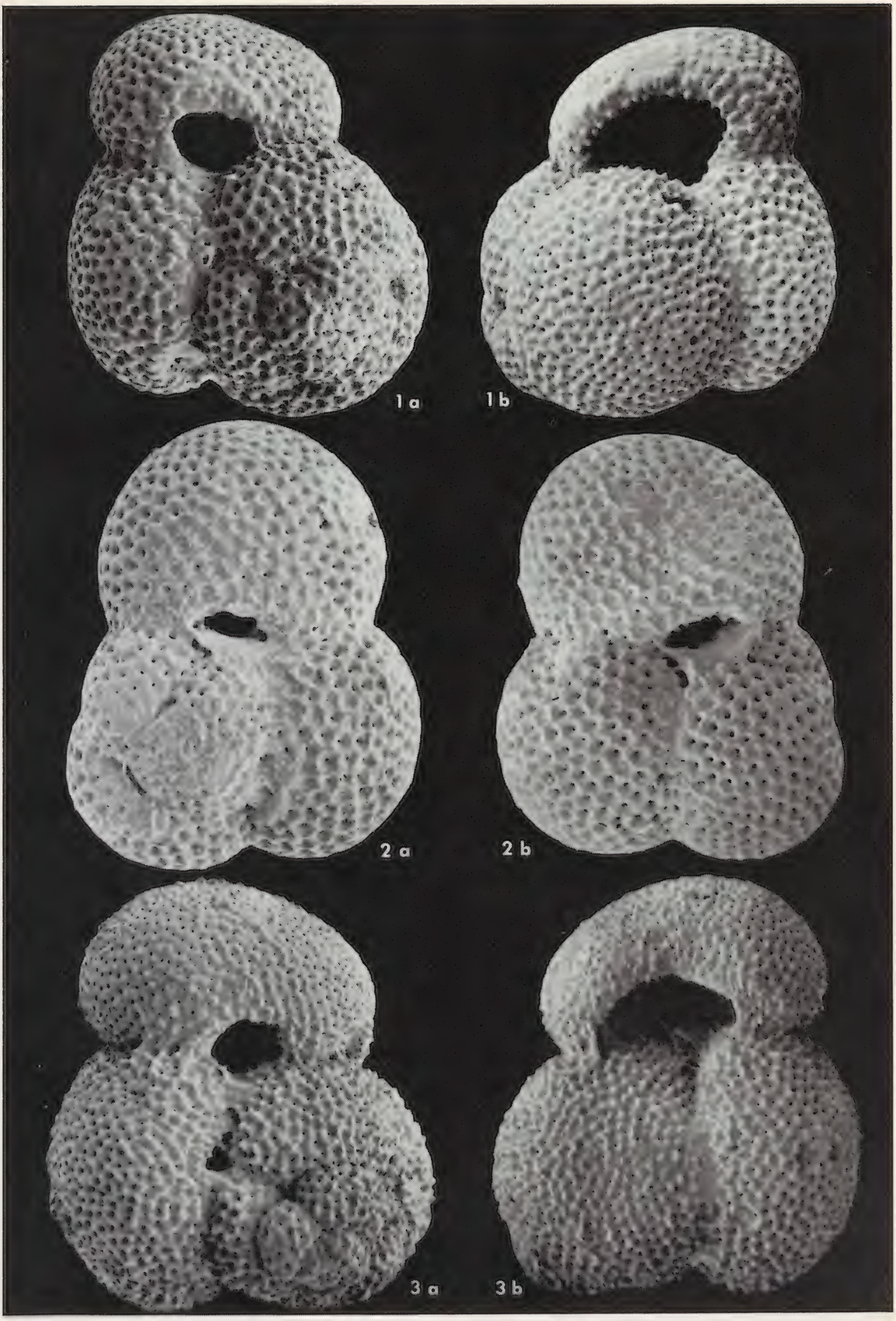


Plate 56

## Genus CASSIGERINELLA Pokorný, 1955

### CASSIGERINELLA CHIPOLENSIS (Cushman and Ponton)

Pl. 1, fig. 1; Pl. 2, fig. 1

*Cassidulina chipolensis* CUSHMAN and PONTON, 1932, Florida Geol. Surv., Bull. 9, p. 98, pl. 15, figs. 2a-c.

*Cassidulina chipolensis* Cushman and Ponton. CUSHMAN and STAINFORTH, 1945, Cushman Lab. Foram. Res., Spec. Publ. 14, p. 64, pl. 12, fig. 5.

*Cassigerinella boudecensis* POKORNÝ, 1955, Ustr. Ust. Geol., Vestnik, Prague, vol. 30, pp. 137, 138, pls. 1-3.

*Cassigerinella chipolensis* (Cushman and Ponton). BOLLI, 1957, U. S. Natl. Mus., Bull. 215, p. 108, pl. 22, figs. 3a-c.

*Cassigerinella globolocula* IVANOVA *in* BYKOVA *et al.*, 1958, Trudy VNIGRI, vol. 115, no. 9, p. 57, pl. 11, figs. 1-3.

*Cassigerinella chipolensis* (Cushman and Ponton). CORDEY, 1968, Palaeontology, vol. 11, pt. 3, pp. 368-370, text-fig. 1, figs. f-m.

"Test minute, consisting of subglobular chambers, four pairs making up the last whorl, periphery strongly lobulated; chambers very distinct, inflated, in alternating pairs at each side of the axis of coiling extending over slightly onto the opposite side at the periphery; sutures deeply depressed, distinct; wall smooth, finely perforate; aperture a definite elongate opening in the line of coiling. It is a very small, easily overlooked species, but very distinct in the character of its globular chambers." (Cushman and Ponton, 1932)

Holotype: USNM 16326; Chipola Formation, "USGS Locality 19, at mouth of Senterfeit Branch, a small branch entering the Chipola River 1/2 mile below the type locality of the Chipola Formation on McClelland's farm, Calhoun County, Florida." (See Cushman and Ponton, 1932, p. 15 and fig. 1; this locality is probably TU 1020.)

*Discussion:* *Cassigerinella globolocula* Ivanova and *C. boudecensis* Pokorný are placed in synonomy with *C. chipolensis* on the basis of remarks by V. Pokorný *in* Eames *et al.* (1962, p. 83). Examination of the various species referred to this genus by means of the scanning electron microscope would be helpful in evaluating their validity. *C. eocaenica* Cordey should be included in such a study. The maximum diameter of the holotype of Cushman and Ponton is 0.17 mm, as calculated from the magnification of their type figure. Most of the Chipola localities sampled for this report yielded *C. chipolensis,* and most of the specimens were too small to be retained on a U. S. Standard sieve no. 120.

The range of *C. chipolensis* is from within the earlier part of Zone P. 18 to within the later part of Zone N. 13, and *C. eocaenica* is found from Zone P. 16 to the early part of Zone P. 19, according to Blow (1969, pp. 377-378).

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## PLATE 57
## WACCAMAW FORMATION
## TU 870

Figures Page

1. *Globorotalia (Turborotalia) acostaensis humerosa* Takayanagi and Saito. . . . . 108
   Maximum diameter, 0.52 mm
   a. Spiral view, X 118
   b. Umbilical view, X 115

2. *Globorotalia (Turborotalia) inflata* (d'Orbigny). . . . . 112
   Maximum diameter, 0.46 mm
   a. Spiral view, X 119
   b. Umbilical view, X 119

3. *Globigerina bulloides bulloides* d'Orbigny. . . . . 48
   Maximum diameter, 0.57 mm
   a. Spiral view, X 120
   b. Umbilical view, X 120

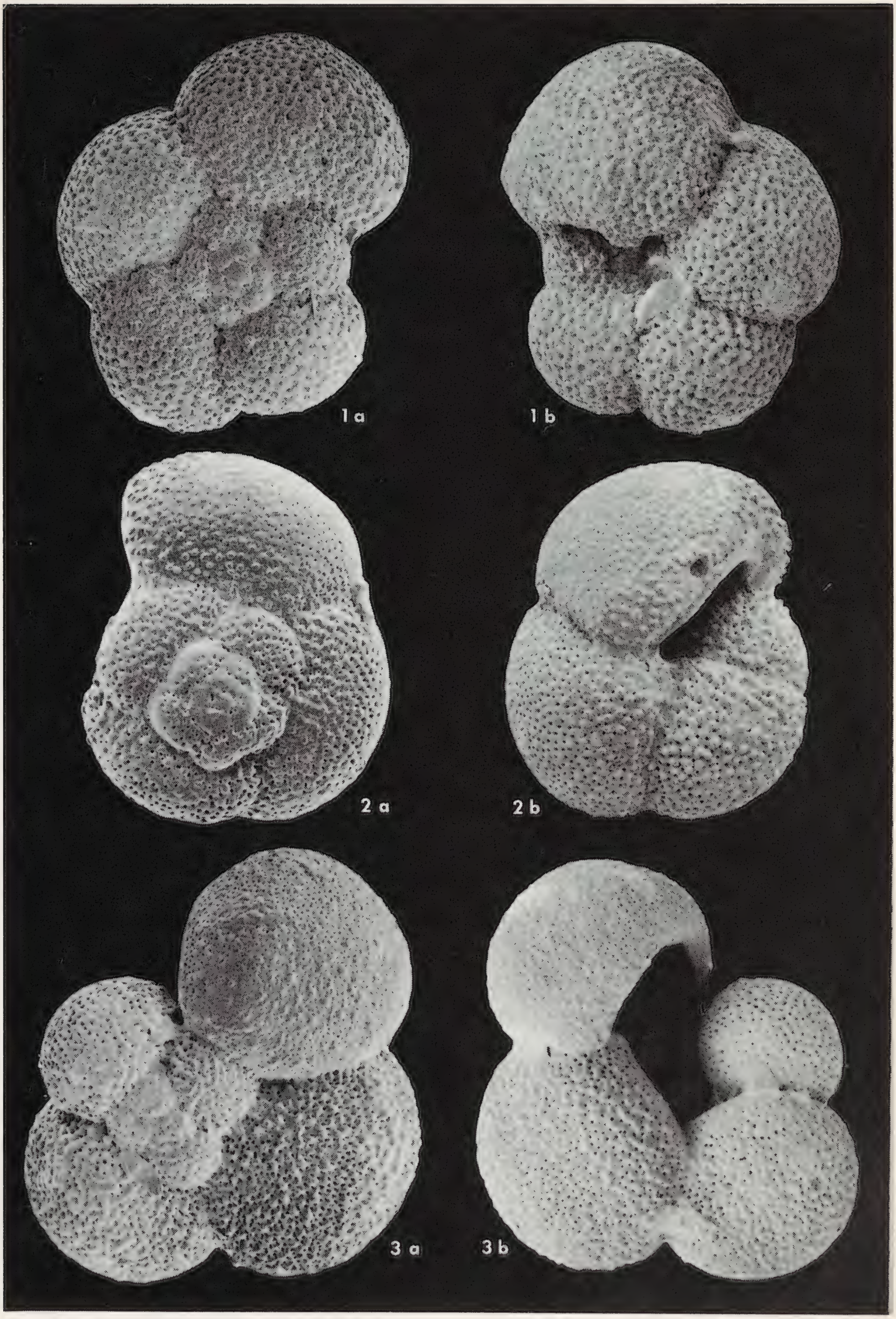


Plate 57

## VII. SUPPLEMENTARY LOCALITY DATA

In addition to those localities described in the text, material was also examined from the following Tulane University Department of Geology localities.

Chipola Formation, all sites located in Calhoun County, Florida:

458. Chipola River, east bank, about 0.3 mile north of Farley Creek, NE 1/4, SW 1/4, sec. 20, T1N, R9W.
459. Chipola River, east bank, about 0.4 mile south of Farley Creek, SE 1/4, NW 1/4, sec. 29, T1N, R9W.
546. Tenmile Creek, north bank, about 0.5 mile east of Florida Highway 73, SW 1/4, NE 1/4, sec. 12, T1N, R10W.
547. Chipola River, west bank, NW 1/4, SW 1/4, sec. 29, T1N, R9W.
548. Chipola River, west bank, about 0.3 mile south of Farley Creek, NE 1/4, NW 1/4, sec. 29, T1N, R9W.
549. Chipola River, east bank, NW 1/4, NE 1/4, sec. 32, T1N, R9W.
550. Chipola River, east bank, about 0.6 mile north of Farley Creek, SW 1/4, NE 1/4, sec. 20, T1N, R9W.
551. Chipola River, east bank, about 1/2 mi. below Four Mile Creek, NE 1/4, sec. 32, T1N, R9W, last outcrop of Chipola Formation.
554. Chipola River, east bank, at power line crossing, SE 1/4, SW 1/4, sec. 17, T1N, R9W.
555. Chipola River, east bank, NE 1/4, SW 1/4, sec. 29, T1N, R9W.
655. Tenmile Creek, north bank, about 0.1 mile east of Florida Highway 73, SW 1/4, NW 1/4, sec. 12, T1N, R10W.
711. Chipola River, west bank, about 0.3 mile north of Farley Creek, NE 1/4, SW 1/4, sec. 20, T1N, R9W.
806. Chipola River, west bank, about 0.4 mile south of power line crossing, NE 1/4, NW 1/4, sec. 20, T1N, R9W.
818. Farley Creek, south bank, about 400 feet west of Florida Highway 275, SW 1/4, SW 1/4, sec. 21, T1N, R9W.
820. Farley Creek, upper beds, north bank, immediate vicinity of Florida Highway 275 bridge, SE 1/4, SW 1/4, sec. 21, T1N, R9W.
822. Farley Creek, south bank, 1/4 mile east of bridge on Florida Highway 275, SW 1/4, sec. 21, T1N, R9W.
825. Farley Creek, north bank, at site of abandoned mill, NW 1/4, SW 1/4, sec. 21, T1N, R9W.
830. Tenmile Creek, north bank, at power line crossing, SE 1/4, SE 1/4, sec. 12, T1N, R10W.

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## PLATE 58
## MOÍN FORMATION

Figures Page

1. *Globigerinoides conglobatus conglobatus* (Brady). . . . . 56
Maximum diameter, 0.62 mm
a. Spiral view, X 84
b. Umbilical view, X 84

2. *Globigerinoides conglobatus conglobatus* (Brady). . . . . 56
Maximum diameter, 0.53 mm
a. Spiral view, X 94
b. Umbilical view, X 94

3. *Globigerinoides obliquus obliquus* Bolli. . . . . 60
Maximum diameter, 0.60 mm
a. Spiral view, X 98
b. Umbilical view, X 98

4. *Globigerinoides ruber* (d'Orbigny). . . . . 66
Maximum diameter, 0.59 mm
a. Side view, X 115
b. Umbilical view, X 115

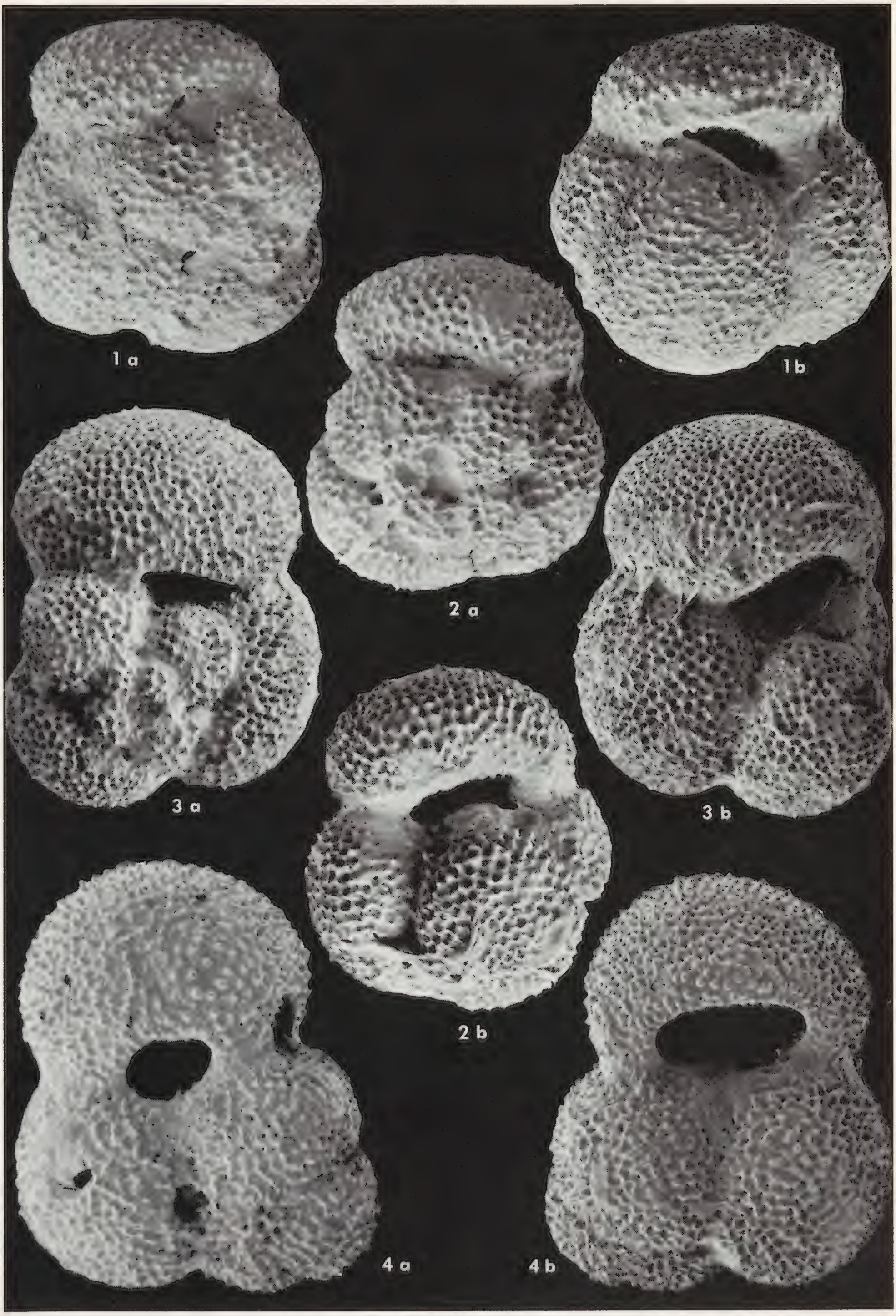


Plate 58

950. Chipola River, west bank, about 2000 feet above mouth of Farley Creek, SW 1/4, sec. 20, T1N, R9W.
951. Tenmile Creek, south bank, just under foot bridge on property of Mr. A. Sexton, about 1 1/4 mile west of Chipola River, SE 1/4, sec. 12, T1N, R10W.
998. Tenmile Creek, north bank, at beginning (west end) of long straight stretch, SE 1/4, sec. 12, T1N, R10W.
999. Farley Creek, south bank, about 1000 yards downstream (west) of bridge on Florida Highway 275, SW 1/4, sec. 21, T1N, R9W.
1019. Chipola River, east bank, about 2000 feet downstream from power line crossing, NW 1/4, sec. 20, T1N, R9W.
1020. Chipola River, in small tributary on east bank, about 1/2 mile below power line crossing, NE 1/4, sec. 20, T1N, R9W.
1021. Tenmile Creek, next big bend upstream from TU 546, north side, NW 1/4, sec. 12, T1N, R10W.

Yorktown Formation:

613. Rice's Pit. On Harris Creek Road, near junction with Fox Hill Road (State Highway 167), just off U. S. Highway 258, Hampton, Virginia.
843. Wilson's Marl Pits. 0.2 miles northeast of Armistead Avenue (= Virginia 172) on Tide Mill Lane (0.9 miles north of U. S. 258), Hampton (York Co.), Virginia.
1022. Lee Creek Mine (Texas Gulf Sulphur Company), at Aurora, North Carolina.
——— Lone Star Cement Pit, Chuckatuck, Virginia. Collected by Wayne E. Moore, 1956.

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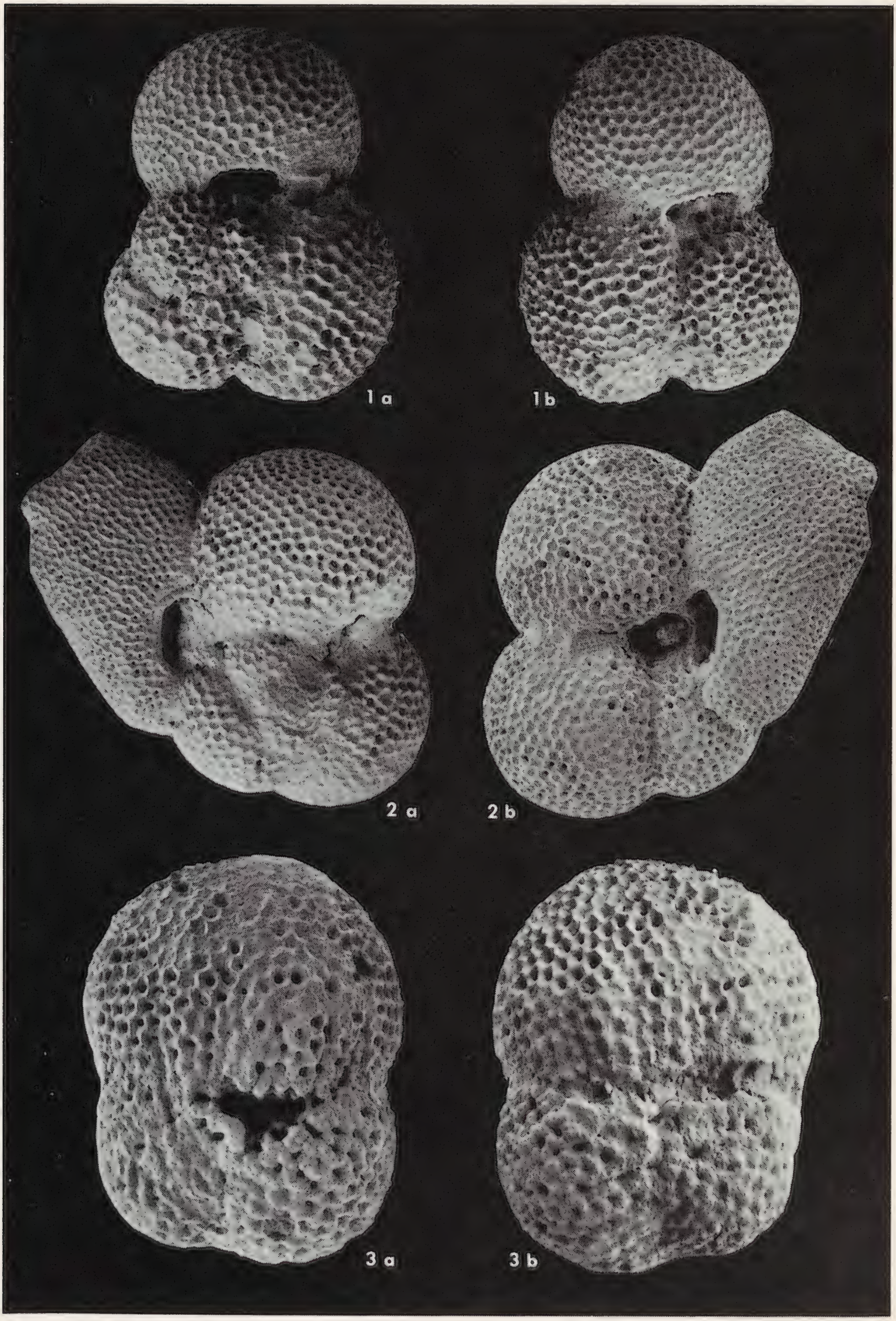
## PLATE 59
## MOÍN FORMATION

Figures Page

1. *Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny). . . . . 62
Maximum diameter, 0.64 mm
a. Spiral view, X 86
b. Umbilical view, X 85

2. *Globigerinoides quadrilobatus sacculifer* (Brady). . . . . 64
Maximum diameter, 0.90 mm
a. Spiral view, X 76
b. Umbilical view, X 78

3. *Sphaeroidinella dehiscens dehiscens* (Parker and Jones). . . . . 78
Maximum diameter, 0.60 mm
a. Spiral view, X 98
b. Umbilical view, X 98

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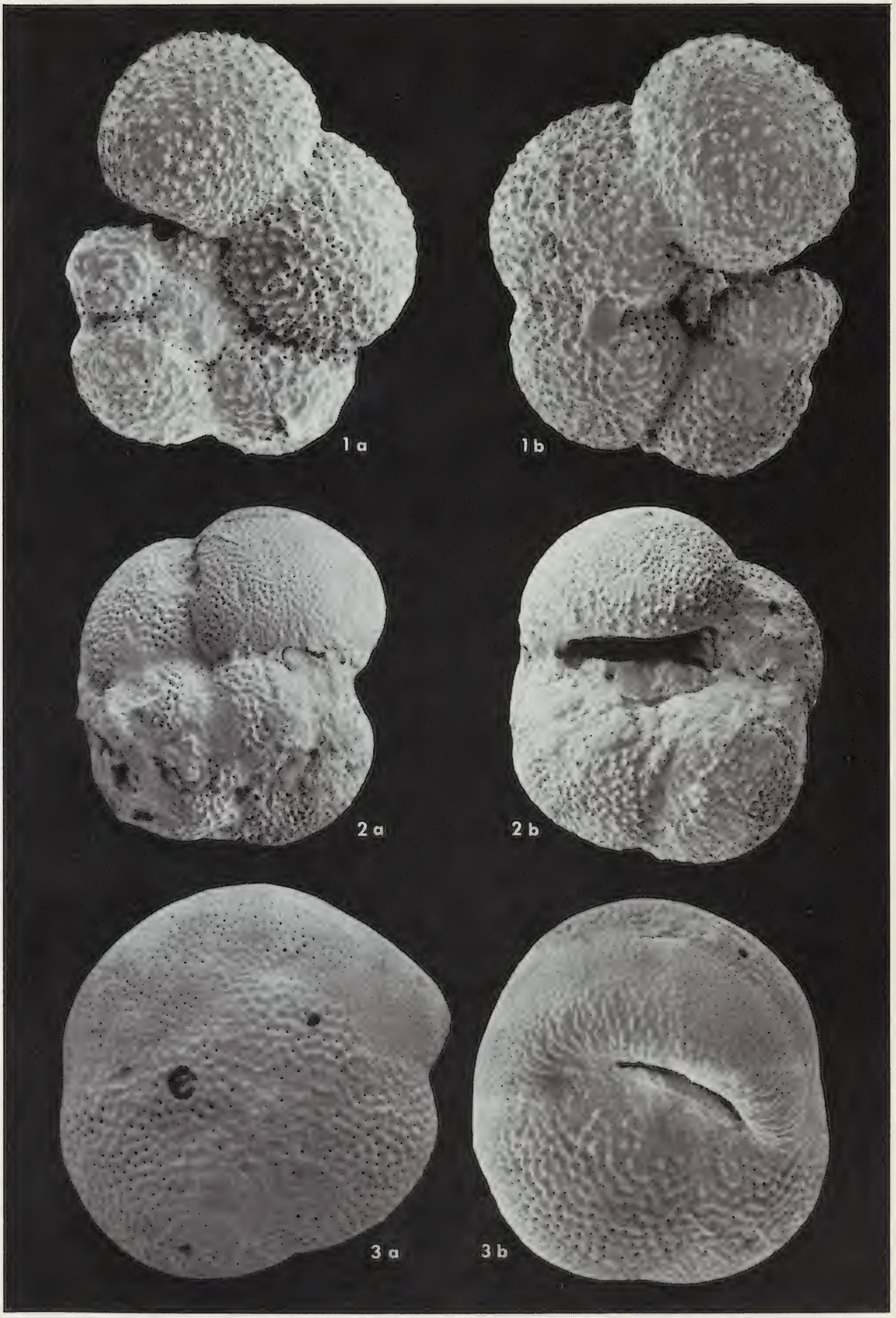
## PLATE 60
## MOÍN FORMATION

Figures — Page

1. *Hastigerina (Hastigerina) siphonifera siphonifera* (d'Orbigny). . . . . 124
Maximum diameter, 0.53 mm
   a. Spiral view, X 119
   b. Umbilical view, X 120

2. *Globoquadrina dutertrei* (d'Orbigny). . . . . 94
Maximum diameter, 0.51 mm
   a. Spiral view, X 101
   b. Umbilical view, X 104

3. *Pulleniatina obliquiloculata obliquiloculata* (Parker and Jones). . . . . 126
Maximum diameter, 0.50 mm
   a. Spiral view, X 120
   b. Umbilical view, X 120

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LOUISIANA AS IT IS: A Geographical and Topographical Description of the State, by Samuel H. Lockett, edited and with an introduction by Lauren C. Post. Published by Louisiana State University Press, Baton Rouge, 1969, xvi + 148 pp., 4 maps, $12.50

This is the first publication in full of the text of the manuscript completed by Lockett in 1873. Lockett chose the title himself, and only minor alterations in punctuation and spelling were made in his original text, which is highly readable and quite useful to geologists, geographers, historians and other scholars interested in Louisiana as it looked in the early 1870's. Lockett's map was published in 1876 and again with revisions in 1891. The 1891 version is reproduced here. The quality and manner of the Lockett Survey is such that the geographical data are as accurate now as when the map was first drawn, except where subsequent changes have taken place, chiefly in the coastal parishes. The original manuscript failed to attract a publisher in its own time, but at a later date came into the possession of the Howard Library in New Orleans (now Howard-Tilton Memorial Library at Tulane) and was preserved. Fortunately, this valuable topographical description of Louisiana is now available in its entirety.

THE TECTONICS OF THE APPALACHIANS, by John Rodgers. Published by Wiley–Interscience, New York, London, Sydney and Toronto, 1970, xiv + 271 pp., large folding tectonic map, $24.00

This is a volume in the *Regional Geology Series,* edited by L. U. De Sitter. It is the first attempt to provide a synthesis of the geology and history of the Appalachian Region, from the vast literature on this important area. The four distinct belts of the southern Appalachians and the less regular subdivisions of the northern portion are treated individually with a separate section for the Triassic basins. Following these chapters, the geological history of the area is summarized, and the volume is concluded with a discussion of the external relations of the Appalachian orogenic belt. The large tectonic map of the Appalachians is in two sections and serves to illustrate the text as well as to display an overall view of the structures of the region. An extensive bibliography and a good index are included.

SEXUAL DIMORPHISM IN FOSSIL METAZOA AND TAXONOMIC IMPLICATIONS, edited by G. E. G. Westermann. Published by E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart, 1969, iv + 251 pp., $12.80

A symposium organized by the International Paleontological Union, Committee on Evolution, held in August, 1968, as part of the XXIII International Congress in Prague is the source of the papers presented in this useful volume, which represents a progress report of research into the sexual behaviour of fossil groups. There are 25 papers included, dealing with five of the major phyla in some detail as well as general topics and analytical techniques.

THE TAXONOMY, MORPHOLOGY AND ECOLOGY OF RECENT OSTRACODA, edited by John W. Neale. Published by Oliver & Boyd, Edinburgh, 1969, x + 553 pp., 9 plates, $30.80 (distributed in the USA by Stechert-Hafner Service Agency, Inc., Darien, Connecticut).

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Prelit

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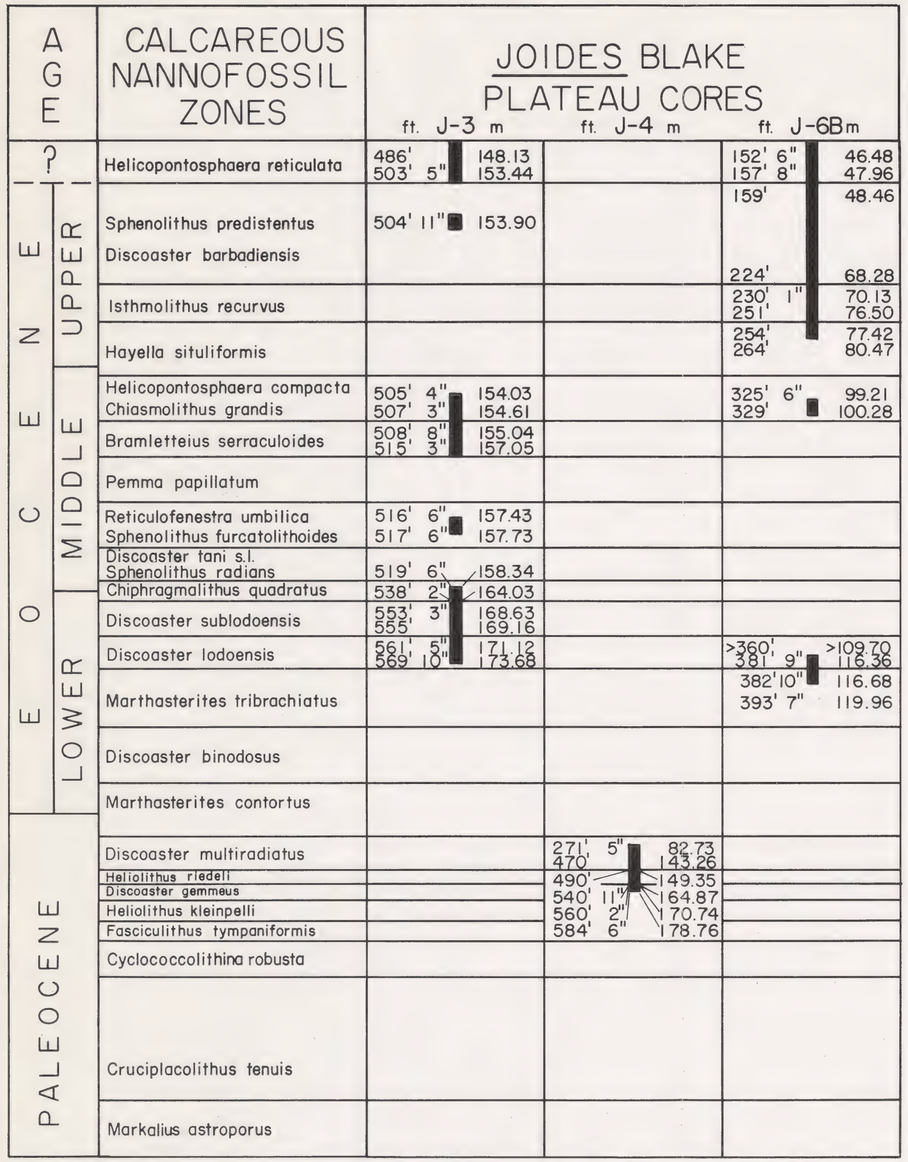
| AGE | | PLANKTONIC FORAMINIFER ZONES (modified after Blow, 1969) | | CALCAREOUS NANNOFOSSIL ZONES | SIGNIFICANT NANNOFOSSIL DATUM LEVELS |
|---|---|---|---|---|---|
| EOCENE | UPPER | ? | | Helicopontosphaera reticulata | Discoaster barbadiensis extinction datum |
| | | P 16 | Cribrohantkenina inflata | Sphenolithus predistentus<br>Discoaster barbadiensis | Sphenolithus pseudoradians<br>Sphenolithus predistentus datum |
| | | P 15 | Globigerapsis mexicana | Isthmolithus recurvus | |
| | | | | Hayella situliformis | Helicopontosphaera reticulata datum |
| | MIDDLE | P 14 | Truncorotaloides rohri | Helicopontosphaera compacta<br>Chiasmolithus grandis | Discoaster saipanensis datum |
| | | P 13 | Orbulinoides beckmanni | Bramletteius serraculoides | Bramletteius datum |
| | | P 12 | Globorotalia lehneri | Pemma papillatum | |
| | | P 11 | Globigerapsis kugleri | Reticulofenestra umbilica<br>Sphenolithus furcatolithoides | Reticulofenestra datum |
| | | P 10 | Hantkenina aragonensis | Discoaster tani s.l.<br>Sphenolithus radians | Chiphragmalithus quadratus datum |
| | LOWER | P 9 | Acaranina densa | Chiphragmalithus quadratus<br>Discoaster sublodoensis | |
| | | P 8 | Globorotalia aragonensis | Discoaster lodoensis | |
| | | P 7 | Globorotalia formosa | Marthasterites tribrachiatus | Cyclococcolithina gammation datum |
| | | P 6 b | Globorotalia subbotinae<br>Pseudohastigerina wilcoxensis | Discoaster binodosus | Chiasmolithus grandis datum |
| | | P 6 a | Globorotalia velascoensis<br>Globorotalia subbotinae | Marthasterites contortus | Marthasterites datum |
| PALEOCENE | | P 5 | Globorotalia velascoensis | Discoaster multiradiatus | Discoaster multiradiatus datum |
| | | P 4 | Globorotalia pseudomenardii | Heliolithus riedeli<br>Discoaster gemmeus | Discoaster gemmeus datum |
| | | P 3 | Globorotalia pusila<br>Globorotalia angulata | Heliolithus kleinpelli<br>Fasciculithus tympaniformis | |
| | | P 2 | Globorotalia uncinata<br>Globorotalia spiralis | Cyclococcolithina robusta | Chiasmolithus bidens datum |
| | | P 1 c | Globoconusa daubjergensis / Globorotalia pseudobulloides | G. compressa<br>G. inconstans<br>G. trinidadensis | Cruciplacolithus tenuis |
| | | P 1 b | | G. triloculinoides | |
| | | P 1 a | | G. pseudobulloides | Markalius astroporus |
| | | | Globigerina eugubina | | |

Markalius astroporus
Cruciplacolithus tenuis
Zygodiscus sigmoides
Chiasmolithus danicus
Ellipsolithus macellus
Cyclococcolithina robusta
Towerius craticulus
Chiasmolithus bidens
Fasciculithus tympaniformis
Heliolithus kleinpelli
Discoaster distinctus
Scapholithus apertus
Towerius gemmeus
Sphenolithus primus
Heliolithus riedeli
Discoaster amarmorgus
Campylosphaera dela
Discoaster medcosus
Fasciculithus multiradiatus
Rhomboaster calcitrapa *
Discoaster mirus *
Marthasterites calcitrapa *
Marthasterites hunnii
Chiasmolithus contortus
Discoasteroides tribrachiatus
Chiphragmalithus grandis
Discoaster megastypus
Discoaster lodoensis
Chiasmolithus solitus
Coccolithus expansus
Cyclococcolithina crassus
Helicopontosphaera kuepperi
Helicopontosphaera gammation
Sphenolithus seminulum seminulum
Helicopontosphaera seminulum lophota
Discoaster radians
Cyclococcolithina barbadiensis
Discoaster barbadiensis
Rhabdosphaera subdodoensis
Triquetrorhabdulus formosa
Thoracosphaera inflata
Chiphragmalithus inversus
Sphenolithus praeprocta
Chiasmolithus furcatolithoides
Micrantholithus acanthoides
Chiphragmalithus solitus
Chiasmolithus procerus
Sphenolithus quadratus
Sphenolithus gigas
Discoaster stellatus *
Chiasmolithus tani nodifer
Reticulofenestra tani tani
Reticulofenestra titus **
Lanternithus minutus
Pemma papillatum
Daktylethra sensura
Cyclococcolithina punctulata
Bramletteius serraculoides
Coccolithus reticulata
Discoaster fissuratus
Helicopontosphaera lophota
Helicopontosphaera seminulum
Coronocyclus larvalis
Helicopontosphaera compacta
Chiasmolithus serratus
Hayella situliformis
Helicopontosphaera wilcoxonii *
Helicopontosphaera ramaruensis
Ferrariolithus salillomi *
Syracosphaera reticulata
Helicopontosphaera labrosa
Isthmolithus recurvus
Sphenolithus predistentus
Scapholithus fossilis
Sphenolithus pseudoradians
Quinqueriabdus colossicus

* = NEW SPECIES
** = NEW SPECIES, IN PRESS

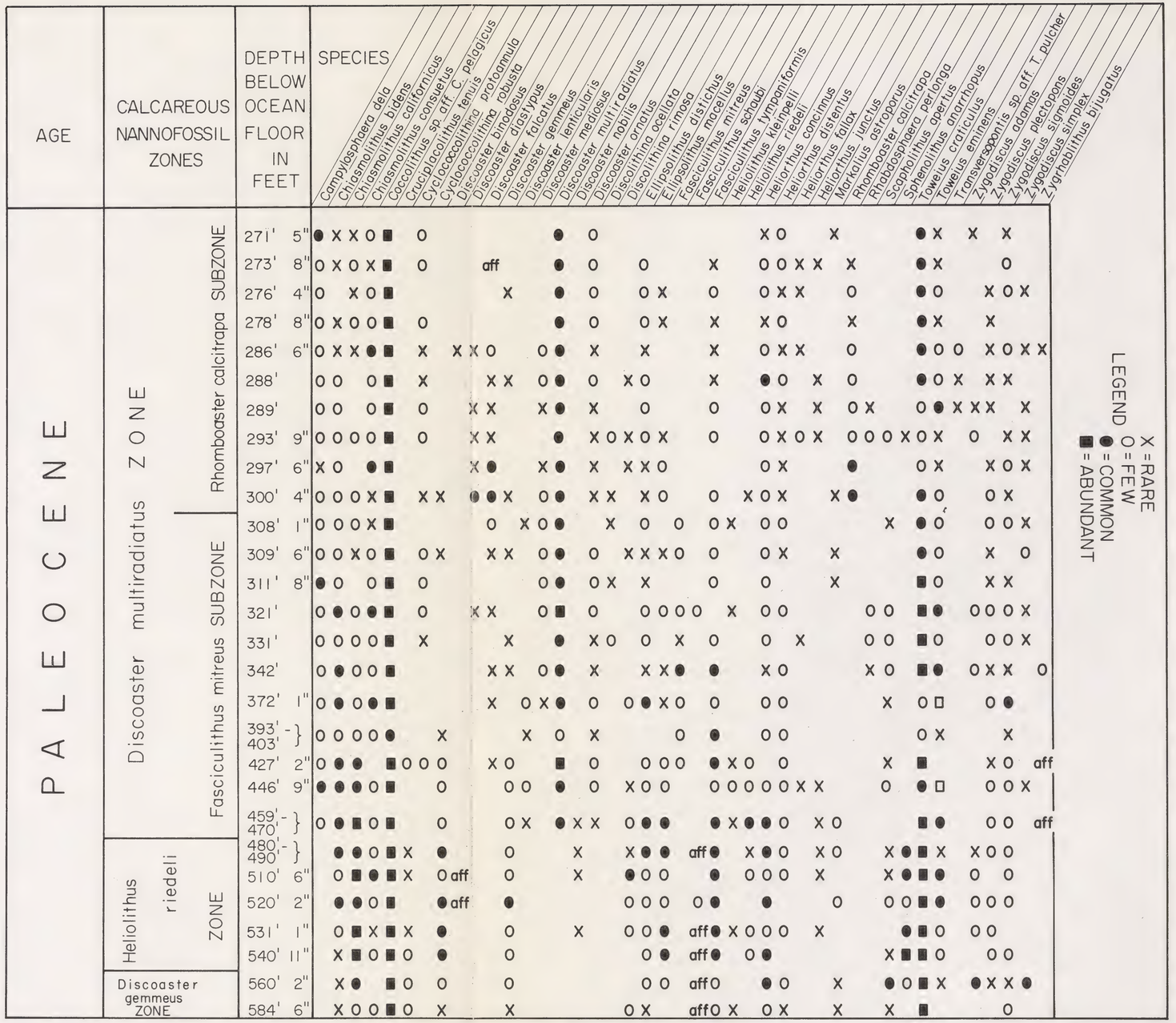
Ranges of selected nannofossil species in the Paleocene and Eocene

Figure 1




Age determination of parts of JOIDES Blake Plateau cores J-3, J-4, and J-6B

Figure 2




Paleogene calcareous nannofossils in core J-4

Figure 3

| AGE | | PLANKTONIC FORAMINIFER ZONES (modified after Blow, 1969) | CALCAREOUS NANNOFOSSIL ZONES |
|---|---|---|---|
| EOCENE | UPPER | P 17 Globigerina gortanil / Globorotalia centralis | Helicopontosphaera reticulata |
| | | P 16 Cribrohantkenina inflata | Sphenolithus predistentus / Discoaster barbadiensis |
| | | P 15 Globigerapsis mexicana | Isthmolithus recurvus |
| | | | Hayella situliformis |
| | MIDDLE | P 14 Truncorotaloides rohri | Helicopontosphaera compacta / Chiasmolithus grandis |
| | | P 13 Orbulinoides beckmanni | Bramletteius serraculoides |
| | | P 12 Globorotalia lehneri | Pemma papillatum |
| | | P 11 Globigerapsis kugleri | Reticulofenestra umbilica / Sphenolithus furcatolithoides |
| | | P 10 Hantkenina aragonensis | Discoaster tani s.l. / Sphenolithus radians |
| | | | Chiphragmalithus quadratus |
| | LOWER | P 9 Acaranina densa | Discoaster sublodoensis |
| | | P 8 Globorotalia aragonensis | Discoaster lodoensis |
| | | P 7 Globorotalia formosa | Marthasterites tribrachiatus |
| | | P 6 b Globorotalia subbotinae / Pseudohastigerina wilcoxensis | Discoaster binodosus |
| | | P 6 a Globorotalia velascoensis / Globorotalia subbotinae | Marthasterites contortus |
| PALEOCENE | | P 5 Globorotalia velascoensis | Discoaster multiradiatus |
| | | P 4 Globorotalia pseudomenardii | Heliolithus riedeli |
| | | | Discoaster gemmeus |
| | | P 3 Globorotalia pusila / Globorotalia angulata | Heliolithus kleinpelli |
| | | P 2 Globorotalia uncinata / Globorotalia spiralis | Fasciculithus tympaniformis |
| | | P 1 c Globoconusa daubjergensis / Globorotalia pseudobulloides: G. compressa, G. inconstans, G. trinidadensis | Cyclococcolithina robusta |
| | | P 1 b Globoconusa daubjergensis / Globorotalia pseudobulloides: G. triloculinoides | Cruciplacolithus tenuis |
| | | P 1 a Globoconusa daubjergensis / Globorotalia pseudobulloides: G. pseudobulloides | |
| | | Globigerina eugubina | Markalius astroporus |

SPECIES: Markalius astroporus; Cruciplacolithus tenuis; Zygodiscus sigmoides; Chiasmolithus consuetus; Ellipsolithus macellus; Cyclococcolithina robusta; Toweius craticulus; Chiasmolithus bidens; Fasciculithus tympaniformis; Heliolithus kleinpelli; Ellipsolithus distichus; Discoaster gemmeus; Scapholithus apertus; Toweius eminens; Sphenolithus primus; Heliolithus riedeli; Discoaster mediosus; Campylosphaera dela; Discoaster multiradiatus; Fasciculithus mitreus *; Rhomboaster calcitrapa *; Discoaster diastypus; Marthasterites nunni; Marthasterites contortus; Chiasmolithus grandis; Discoasteroides megastypus; Chiphragmalithus tribrachiatus; Discoaster lodoensis; Discoaster salsus; Ghiasmolithus kuepperi; Coccolithus expansus; Cyclococcolithina gammation; Helicopontosphaera seminulum seminulum; Sphenolithus radians; Helicopontosphaera seminulum lophota; Cyclococcolithina radians; Discoaster barbadiensis; Rhabdosphaera inflata; Triquetrorhabdulus formosa; Thoracosphaera operculata; Chiphragmalithus acanthodes; Sphenolithus predistentus; Chiasmolithus inversus; Chiphragmalithus procerus; Micrantholithus furcatolithoides; Chiphragmalithus solitus; Chiasmolithus quadratus; Sphenolithus procerus; Discoaster gigas; Chiasmolithus stelligerus *; Discoaster tani nodifer; Discoaster tani tani; Reticulofenestra umbilica; Reticulofenestra titus **; Lanternithus minutus; Pemma papillatum; Daktylethra punctulata; Cyclococcolithina reticulata; Bramletteius serraculoides; Coccolithus floridanus; Discoaster saipanensis; Pedinocyclus gryolis; Coronocyclus serratus; Helicopontosphaera compacta; Chiasmolithus oamaruensis; Hayella situliformis; Helicopontosphaera wilcoxonii *; Petrohalia lophota; Syracosphaera reticulata; Helicopontosphaera joidesa; Isthmolithus recurvus; Helicopontosphaera parallela; Sphenolithus predistentus; Sphenolithus pseudoradians; Quinquerhabdus colossicus

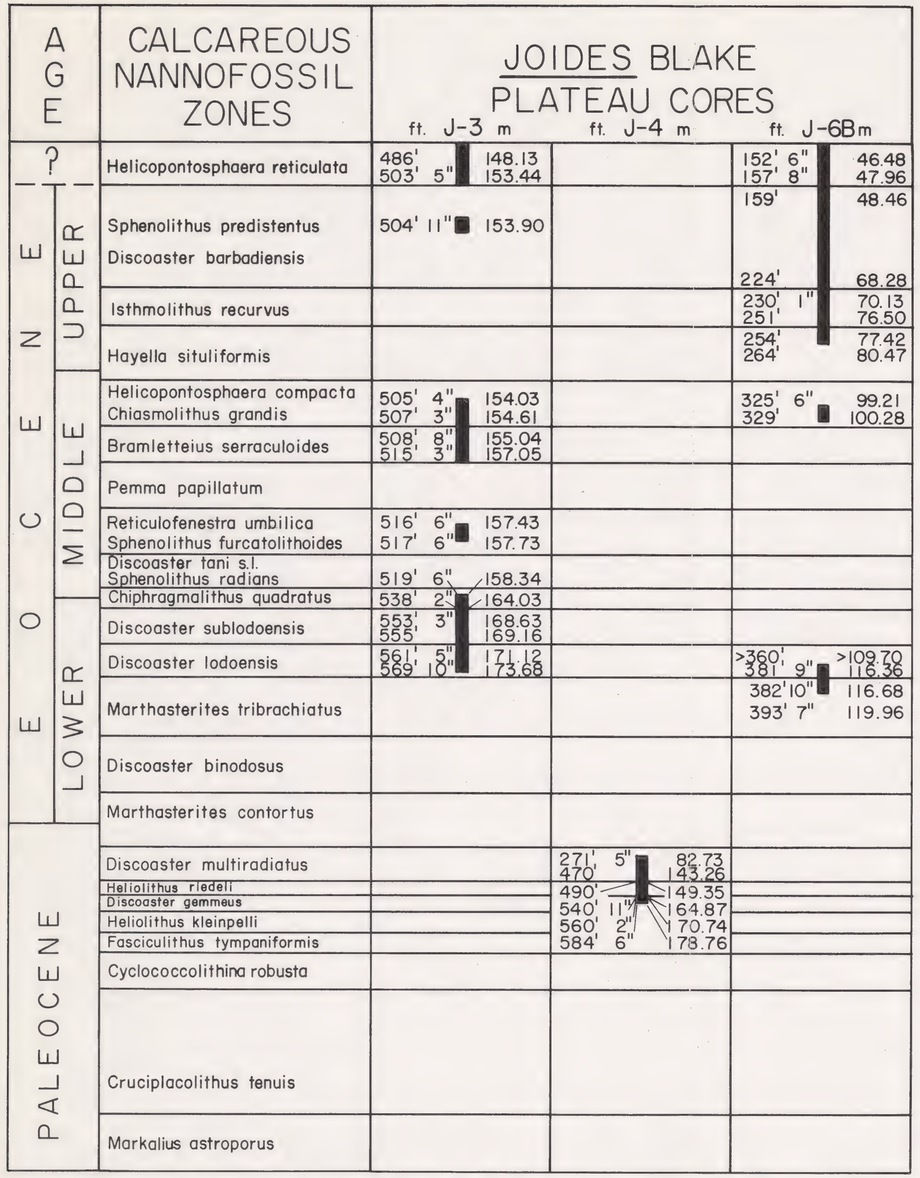
SIGNIFICANT NANNOFOSSIL DATUM LEVELS

- Discoaster barbadiensis extinction datum
- Sphenolithus pseudoradians / Sphenolithus predistentus datum
- Helicopontosphaera reticulata datum
- Discoaster saipanensis datum
- Bramletteius datum
- Reticulofenestra datum
- Chiphragmalithus quadratus datum
- Cyclococcolithina gammation datum
- Chiasmolithus grandis datum
- Marthasterites datum
- Discoaster multiradiatus datum
- Discoaster gemmeus datum
- Chiasmolithus bidens datum

* = NEW SPECIES
** = NEW SPECIES, IN PRESS

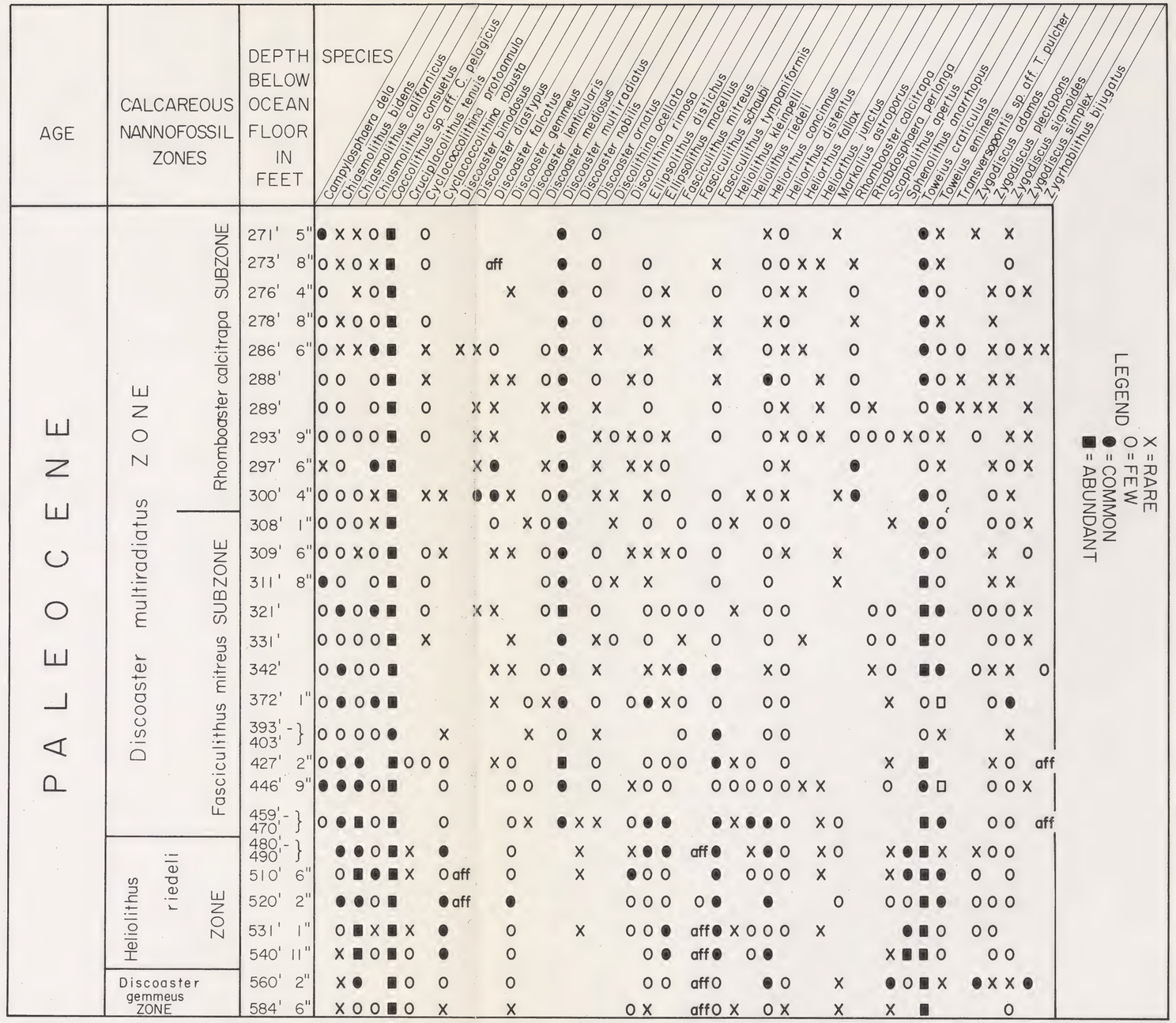
Ranges of selected nannofossil species in the Paleocene and Eocene

Figure 1




Age determination of parts of JOIDES Blake Plateau cores J-3, J-4, and J-6B

Figure 2




Paleogene calcareous nannofossils in core J-4

Figure 3

| AGE | CALCAREOUS NANNOFOSSIL ZONES | DEPTH BELOW OCEAN FLOOR IN FEET | SPECIES |
|---|---|---|---|
| EOCENE — LOWER — MIDDLE (?) — UPPER (?) | Helicopontosphaera reticulata ZONE | 486' | Bramletteius serraculoides ■ |
| | | 488' | Campylosphaera dela ● |
| | | 493' 1" | Chiasmolithus bidens ● |
| | | 496' 10" | Chiasmolithus californicus ● |
| | | 498' 8" | Chiasmolithus consuetus ● |
| | | 503' 5" | Chiasmolithus expansus ● |
| | | 504' 11" | Chiasmolithus gigas □ |
| | | 505' 4" | Chiasmolithus grandis ●○ |
| | | 507' 3" | Chiasmolithus oamaruensis ×● |
| | Bramletteius serraculoides ZONE | 508' 8" | Chiasmolithus solitus × |
| | | 515' 3" | Chiasmolithus titus ○ |
| | Reticulofenestra umbilica ZONE | 516' 6" | Chiphragmalithus acanthodes ×●● |
| | | 517' 6" | Chiphragmalithus calathus × ○ ○○ |
| | | 519' 6" | Coccolithus crassus × ○ ○○ |
| | Chiphragmalithus quadratus ZONE | 523' 10" | Coccolithus cribellum ○ × ○○ |
| | | 527' 3" | Coccolithus eopelagicus ○● |
| | | 528' 3" | Coccolithus floridanus × ○ ○○ |
| | | 536' 2" | Coccolithus marismontrium ○ ● ● |
| | | 538' 2" | Coronocyclus serratus ○ |
| | | 553' 3" | Crucplacolithus staurion ○ ● ● |
| | Discoaster sublodoensis ZONE | 553' 7" | Cyclococcolithina gammation ○ ● ● |
| | | 554' | Cyclococcolithina formosa ○ |
| | | 555' | Cyclococcolithina protamnula ○ |
| | Discoaster lodoensis ZONE | 561' 5" | Cyclolithella reticulata ○ |
| | | 561' 11" | Discoaster bramlettei ○ |
| | | 567' 8" | Discoaster barbadensis ○ |
| | | 568' 6" | Discoaster hilli ○ |
| | | 569' 10" | Discoaster lodoensis ○ |
| | | | Discoaster ornatus ○ |
| | | | Discoaster saipanensis ○ |
| | | | Discoaster salisburgensis ○ |
| | | | Discoaster subgeminus ○ |
| | | | Discoaster tani tani ○ |
| | | | Ellipsolithus kuepperi ○ |
| | | | Ericsonia fenestrata ○ |
| | | | Ericsonia rimosa ○ |
| | | | Hayella situliformis ○ |
| | | | Helicopontosphaera distichus ○ |
| | | | Helicopontosphaera compacta ○ |
| | | | Helicopontosphaera parallela ○ |
| | | | Helicopontosphaera reticulata ○ |
| | | | Helicopontosphaera seminulum lophota ○ |
| | | | Helicopontosphaera seminulum seminulum ○ |
| | | | Helicopontosphaera wilcoxonii ○ |
| | | | Heliorthus fallax ○ |
| | | | Lanternithus minutus ○ |
| | | | Pedinocyclus larvalis ○ |
| | | | Markalius inversus ○ |
| | | | Micrantholithus basquensis ○ |
| | | | Micrantholithus crenulatus ○ |
| | | | Micrantholithus procerus ○ |
| | | | Pemma angulatum ○ |
| | | | Pemma papillatum ○ |
| | | | Perrirachelina joidesa ○ |
| | | | Quinqueharbdus colossicus ○ |
| | | | Reticulofenestra scissura ○ |
| | | | Rhabdosphaera umbilica ○ |
| | | | Sphenolithus distentus ○ |
| | | | Sphenolithus furcatolithoides ○ |
| | | | Sphenolithus moriformis ○ |
| | | | Sphenolithus predistentus ○ |
| | | | Sphenolithus pseudoradians ○ |
| | | | Sphenolithus radians ○ |
| | | | Sphenolithus stellatus ○ |
| | | | Thoracosphaera prolata ○ |
| | | | Triquetrorhabdulus inversus ○ |
| | | | Zygrhablithus bijugatus bijugatus ○ |
| | | | Zygrhablithus bijugatus crassus ○ |

LEGEND
X = RARE
○ = FEW
● = COMMON
■ = ABUNDANT

▨ = Helicopontosphaera compacta / Chiasmolithus grandis ZONE

▨ = Sphenolithus predistentus / Discoaster barbadiensis ZONE

**Paleogene calcareous nannofossils in core J-3**

**Figure 4**

| AGE | | CALCAREOUS NANNOFOSSIL ZONES | DEPTH BELOW OCEAN FLOOR IN FEET |
|---|---|---|---|
| EOCENE | UPPER | Helicopontosphaera reticulata ZONE | 150' 1" |
| | | | 151' 6" |
| | | | 152' 6" |
| | | | 154' 5" |
| | | | 157' 8" |
| | | Sphenolithus predistentus ZONE | 159' |
| | | | 161' 9" |
| | | | 165' |
| | | | 168' |
| | | | 174' 4" |
| | | | 179' |
| | | Discoaster barbadiensis ZONE | 182' 1" |
| | | | 187' 11" |
| | | | 191' |
| | | | 193' 10" |
| | | | 200' 1" |
| | | | 203' |
| | | | 214' 8" |
| | | | 224' |
| | | Isthmolithus recurvus ZONE | 230' 1" |
| | | | 233' 1" |
| | | | 244' 10" |
| | | | 251' |
| | | Hayella situliformis ZONE | 254' |
| | | | 263' |
| | | | 264' |
| | MIDDLE | Helicopontosphaera compacta Chiasmolithus grandis ZONE | 325' 6" |
| | | | 326' 11" |
| | | | 329' |
| | | MIXED INTERVAL | 332' |
| | | | 333' |
| | | | 350'-360' |
| | LOWER | Discoaster lodoensis ZONE | 360'-370' |
| | | | 381' 9" |
| | | Marthasterites tribrachiatus ZONE | 382' 10" |
| | | | 392' 7" |
| | | | 393' 7" |

SPECIES

Blackites sp.
Bramletteius serraculoides
Campylosphaera dela
Chiasmolithus bidens
Chiasmolithus californicus
Chiasmolithus consuetus
Chiasmolithus expansus
Chiasmolithus gigas
Chiasmolithus grandis
Chiasmolithus oamaruensis
Chiasmolithus solitus
Coccolithus eopelagicus
Coccolithus crassus
Coccolithus cribellum
Coccolithus eopelagicus
Coccolithus formosus
Coccolithus marismontium
Coronocyclus floridanus
Coronocyclus germanicus
Cruciplacolithus serratus
Cyclococcolithina formosa
Cyclococcolithina gammation
Cyclococcolithina protoannula
Cyclococcolithina reticulata
Cyclococcolithina torquinius
Cyclolithella bramlettei
Discoaster barbadiensis
Discoaster deflandrei
Discoaster diastypus
Discoaster lodoensis
Discoaster mirus
Discoaster multiradiatus
Discoaster ornatus
Discoaster saipanensis
Discoaster salisburgensis
Discoaster tani nodifer
Discoaster tani tani
Discoaster woodringi
Discoasteroides kupperi
Discoasteroides megastypus
Discolithina oamaruensis
Ellipsolithus pectinata
Ericsonia fenestrata
Hayella situliformis
Helicopontosphaera compacta
Helicopontosphaera parallela
Helicopontosphaera reticulata
Helicopontosphaera seminulum loprata
Helicopontosphaera seminulum seminulum
Helicopontosphaera wilcoxoni
Heliorthus concinnus
Heliorthus distentus
Heliorthus fallax
Isthmolithus recurvus
Lanternithus minutus
Lithostromation perdurum
Lophodolithus nascens
Markalius inversus
Marthasterites tribrachiatus
Micrantholithus crenulatus
Micrantholithus vesper
Pemma angulatum
Pemma papillatum
Perrocheilina joidesa
Pyrocyclus hermosus
Reticulofenestra scissura
Rhabdosphaera umbilica
Rhabdosphaera perlonga
Rhabdosphaera tenuis
Rhabdosphaera spinula
Sphenolithus furcatolithoides
Sphenolithus mariformis
Sphenolithus predistentus
Sphenolithus pseudoradians
Syracosphaera lobrosa
Toweius craticulus
Transversopontis exilis
Transversopontis pulcher
Transversopontis sp. aff. T. pulcher
Zygodiscus plectopons
Zygrhablithus bijugatus bijugatus
Zygrhablithus bijugatus crassus

LEGEND
X = RARE
O = FEW
● = COMMON
■ = ABUNDANT

Paleogene calcareous nannofossils in core J-6B

Figure 5

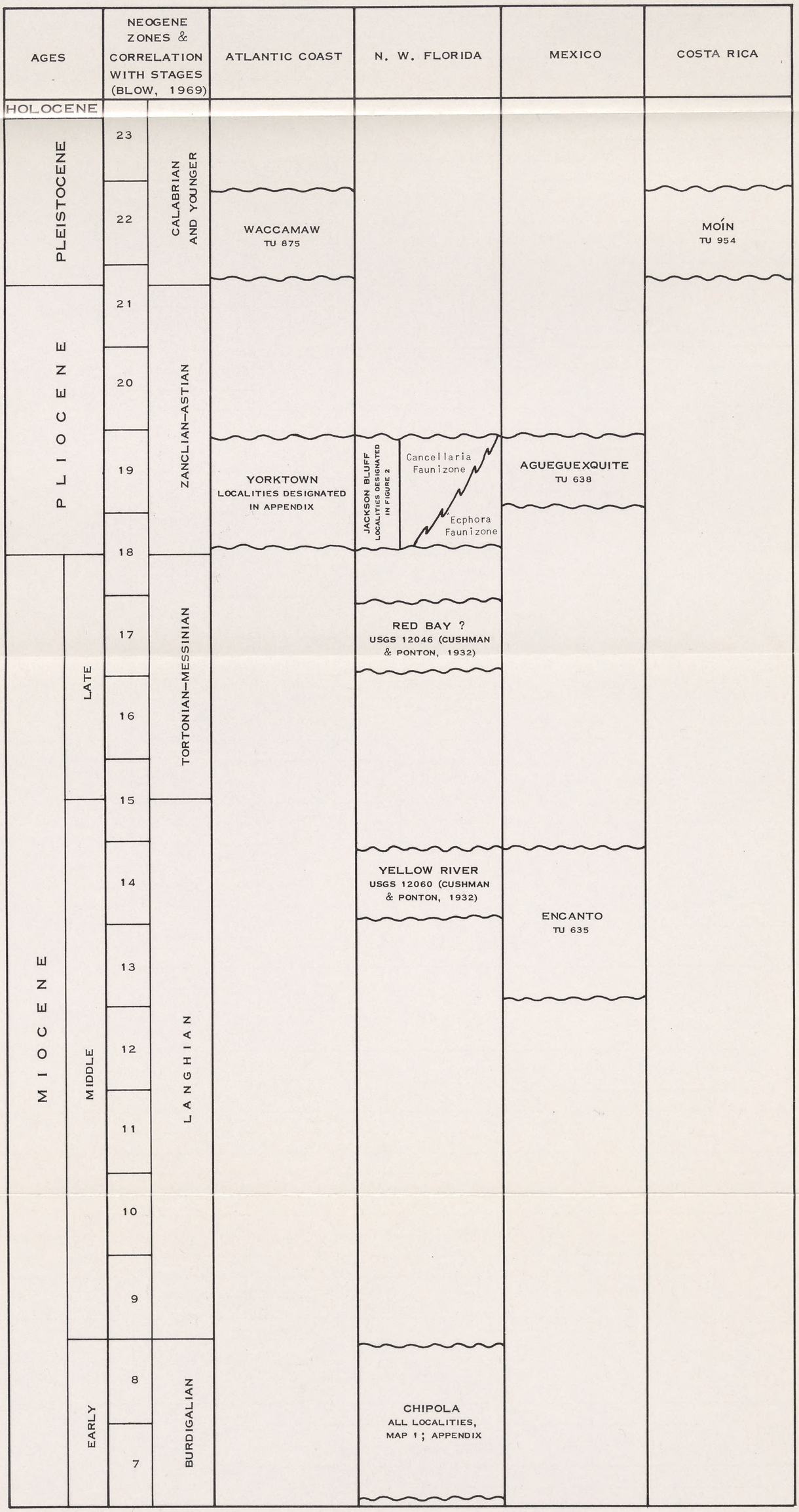



FIGURE 3

CORRELATION OF SOME NEOGENE FORMATIONS

BY MEANS OF PLANKTONIC MICROFOSSILS

NOTE: "FAUNIZONE" IS USED THROUGHOUT THIS REPORT IN THE SENSE OF PURI AND VERNON (1964)

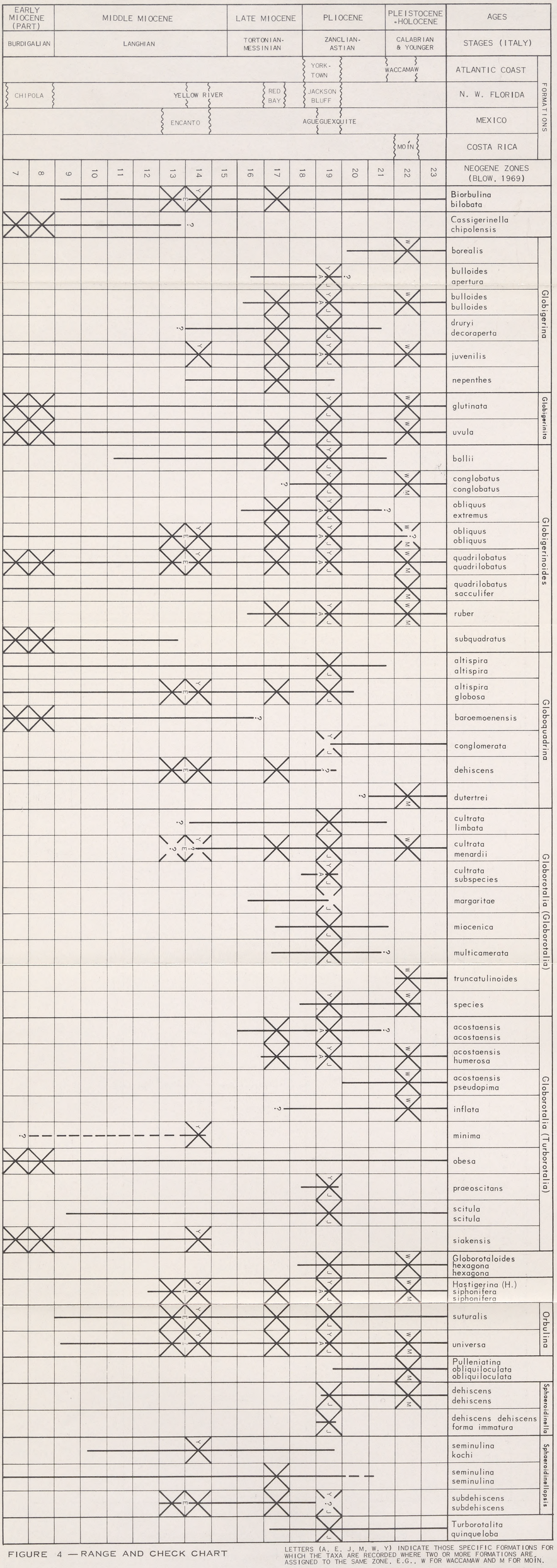



FIGURE 4 — RANGE AND CHECK CHART

LETTERS (A, E, J, M, W, Y) INDICATE THOSE SPECIFIC FORMATIONS FOR WHICH THE TAXA ARE RECORDED WHERE TWO OR MORE FORMATIONS ARE ASSIGNED TO THE SAME ZONE, E.G., W FOR WACCAMAW AND M FOR MOÍN.

RANGES OF SOME PLANKTONIC FORAMINIFERA OCCURRING IN THE INTERVAL FROM EARLY MIOCENE (PART) TO RECENT AND CHECK CHART FOR THESE FORMS FOUND IN FORMATIONS OF THE ATLANTIC AND GULF COASTAL PLAINS. RANGES, ACCORDING TO VARIOUS AUTHORS, ARE IN ALPHABETICAL ORDER.

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